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editorial

Integrated STEm or Integrated STEM?

Integrated STEM learning experiences are recognized in K–12 education as a way to help students apply content area knowledge, make connections between discipline areas, and to advance student understanding and knowledge as a whole (e.g., Furner & Kumar, 2007; National Research Council, 2012). In a meta-analysis of research of integrated approaches among science, technology, engineering, and mathematics, Becker and Park (2011) found that integrated approaches have shown positive learning outcomes for students. Similarly, Stohlmann, Moore, and Roehrig, (2012) found that integrated lessons allow for a more authentic treatment of mathematics and science content. As a result, schools have changed practices and legislation has been created to support integrated STEM learning opportunities for K–12 students (Johnson, 2012).

Although research has identified potential benefits for students who participate in integrated STEM learning experiences, other research has shown that K–12 STEM curricula do not necessarily enhance mathematics and science learning (Tran & Nathan, 2010). In some cases, the integration of mathematics content in a meaningful way has been a challenge for teachers who are creating and implementing integrated STEM lessons. For example, Frykholm and Glasson (2005) found that mathematics was simply used as a tool for computation and data collection. "This perception of 'mathematics as tools' may fall short of how some in the mathematics education community define mathematics and promote its study in the K–12 experience" (Frykholm & Glasson, 2005, p. 139). Integration of mathematics as a tool could be considered a type of context integration (Glancy et al., 2014; Moore et al., 2014) that could help students make connections between the STEM disciplines. At the same time, this type of integration falls short in helping students understand grade-level mathematics learning standards (c.f. Larson, 2017).

Challenges With Integrating Mathematics

When developing integrated STEM lessons, including content to be learned can be challenging. "Combining content from multiple disciplines in a meaningful way is no easy task, and it is important to ensure that the essential aspects of each of the different content areas are not lost through the process of integration" (Glancy et al., 2014). Many of the topics used for integrated STEM lessons create challenges for the inclusion of mathematics content from the beginning. Example topics include energy conservation, water quality, robotics, and recycling. There is definitely mathematics involved in each of these topics. The challenge for teachers and curriculum developers is identifying standards-based and grade-level appropriate mathematics content that aligns with the chosen topic. Related to this challenge is that the mathematics content connections typically identified are measurement and data analysis (Welty, Katehi, Pearson, & Feder, 2008) which represent a small portion of the standards-based mathematics curriculum. Opportunities for learning numeracy, proportional reasoning, linear and non-linear relationships, probability, and mathematical modeling are often not incorporated into the integrated STEM lessons.

A second challenge in creating integrated STEM lessons is the need for content and pedagogical knowledge in each of the discipline areas (Wang, Moore, Roehrig, & Park, 2011). For example, a teacher who specializes in mathematics is likely to have difficulty creating a unit that includes standards-based and grade-level appropriate technology, engineering, and science learning goals. It will also be difficult for the mathematics specialist to understand and address the specialized pedagogical knowledge for all four of the discipline areas.

Addressing the Mathematics Integration Challenge: An Example

From 2013 to 2015, a team of STEM educators and I worked with a Midwestern high school to create and implement content-themed integrated STEM curricular units that would address academic standards in the STEM discipline areas (Vandrevala, Thomas, & Walker, 2015). The partnering high school was departmental-based; having separate science, mathematics, and technology/engineering departments. All of the participating teachers

specialized in a specific content area. The high school had little experience with integrated STEM curriculum. The administration and teachers committed to the work because they identified integrated STEM as a way to improve student interest and achievement. Teachers participated in approximately 80 hours of professional development each year. The professional development work included a summer institute, implementation of curricular units, classroom observations by the STEM educators, and follow-up meetings during the school year.

In the first year, teachers formed multi-disciplinary teams to develop curricular units using the *STEM Integration Curriculum Assessment* (Guzey & Moore, 2013) as a framework of features for an integrated STEM unit. In year one, a teacher team could have an engineering teacher, a biology teacher, a chemistry teacher, an algebra teacher, and a geometry teacher. Teachers created and implemented lessons on weather and flight, continental drift, engineering design, and solar systems. There were two challenges identified by the teachers in the evaluation of the first year (Walker & Bayley, 2017). First, all teachers, especially the mathematics teachers, noted that it was difficult to include standards-based and grade-level mathematics content in the integrated units. Second, teachers noted that it was difficult to teach content and use pedagogical strategies from the disciplines in which they did not specialize.

To address the first-year challenges, two changes were made to the professional development work. First, teacher teams were narrowed by discipline area. In year two, teams had no more than three discipline areas represented and were aligned by grade level. For example, most tenth-grade students enrolled in geometry and chemistry classes, so the geometry and chemistry teachers formed a group. Second, groups were asked to identify mathematics content before considering content from other STEM disciplines. For example, the tenth-grade geometry and chemistry teachers started with the topic of similar triangles. From the topic of similar triangles, the teachers developed a lesson on rocket propulsion that included opportunities for students to learn about the Ideal Gas Law and engineering design.

In the evaluation following the second year, teachers noted that they had an easier time creating integrated STEM lessons and that the content was better aligned with grade-level academic standards (Walker & Bayley, 2017). Part of the ease and perceived alignment is likely due to the teachers having completed a prior year of experience with the *STEM Integration Curriculum Assessment*. Surveys and interviews provided evidence that the teachers felt that starting with a mathematics topic was a key to the improvements in the second year.

Suggestions

Integrated STEM activities and units can provide opportunities for students to meaningfully learn standards-based content and make connections between the STEM disciplines. Teachers and curriculum developers face challenges with addressing the learning of content from multiple discipline areas and with appropriate pedagogical strategies. There is evidence that mathematics content is a particular challenge. In the example, teachers and STEM education experts had additional success starting with a mathematics topic to create integrated STEM units. The following are suggestions to help teachers and curriculum developers create curriculum that will help students learn standards-based and grade-level appropriate STEM content:

- Try starting with a grade-level standards-based mathematics topic for an integrated STEM unit.
- Write out explicit learning objectives for each of the STEM discipline areas represented in the curricular unit.
- Use an integrated STEM framework (e.g. Guzey & Moore, 2013; Johnson, Peters-Burton, and Moore, 2016; Vasquez, Sneider, and Comer, 2013) to guide curriculum development and align pedagogical strategies.
- Work closely with teachers and experts in different STEM areas to learn about the content and pedagogical strategies related to the STEM unit you are developing and/or implementing.

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The *School Science and Mathematics* editorial staff requests the submission of manuscripts for an upcoming special issue on P-12 engineering education. With the increased focused on engineering initiatives in P-12, a better understanding of efforts that are being made to increase student interest and persistence toward engineering is needed. In particular, we are seeking manuscripts on P-12 Engineering Education in the following areas:

- Studies of P-12 teachers and/or schools/districts implementing engineering curriculum/programs
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- Studies of P-12 pre-engineering programs (formal and informal) – growing the engineering pipeline
- Current review of instruments being used to assess engineering education initiatives or related beliefs and attitudes
- Engineering education professional development for preservice and in-service teachers
- Examination of or framework for examining P-12 Engineering focused curriculum

All manuscripts must meet the length and format guidelines for the journal (see the information at http://onlinelibrary.wiley.com/journal/10.1111/(ISSN)1949-8594). A group of Reviewers and Associate Editors will be identified to review the manuscripts.
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Dr. Juliana Utley, Professor of Mathematics Education, Oklahoma State University, will serve as the Guest Editor for this special issue along with Dr. Toni Ivey and Dr. Jennifer Cribbs, Oklahoma State University, as co- Guest Editors. If you have questions regarding the appropriateness of a topic/manuscript for this special issue, please contact Dr. Utley at juliana.utley@okstate.edu.

Peruvian Food Chain Jenga: Learning Ecosystems with an Interactive Model

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A pilot study was conducted on a multimodal educational tool, Peruvian Food Chain Jenga (PFCJ), with 5th-grade students (N = 54) at a public charter school. The goal was to compare the effectiveness of the multimodal tool to a more traditional presentation of the same materials (food chain) using an experimental/control design. Data collection included a pretest/posttest and a "What I Did/What I Learned" response sheet. Quantitative analysis of pretest/posttest results showed both groups improved from pretest to posttest; however, there was no statistically significant difference between posttest results of experimental and control groups. Qualitative analysis of student open-ended responses indicated a difference between students who used the PFCJ and students in the control. The most striking difference occurred in how the students perceived the connectedness of species and the awareness of human impact. Our findings suggest that using a model such as PFCJ as a means of teaching and connecting scientific content with practices related to ecosystems is an effective method of engaging students in intelligent discussions about these topics.

A persistent challenge in science teacher education is assisting in-service and preservice teachers in creating an optimum learning environment within their classrooms. To meet this challenge, science teacher educators need to know the content required by state and national standards, topics teachers consider to be important, areas teachers find challenging to teach, and tools best suited to help K–12 students learn. In addition, science teacher educators need to be able to help teachers see ways to connect the big ideas of science by using appropriate pedagogical approaches.

Ecology (with the disciplinary core idea of interdependent relationships in ecosystems) (Next Generation Science Standards [NGSS Lead States], 2013; Texas Education Agency [TEA], n.d.) is one content area that is introduced over the elementary grades and revisited in middle and high school. Therefore, teachers at all grade levels need to have an understanding of ecological complexity and be able to teach about many aspects of ecosystems. Historically, the concepts related to ecology have held a high priority. In a study asking teachers to rate the importance of content areas for their students, food webs were rated as one of 15 most important items in the biology curricula (Finley, Stewart, & Yarroch, 1982). More recently, the National Science Education Standards (NSES) (NRC, 1996), NGSS (NGSS Lead States, 2013), and Texas Essential Knowledge and Skills (TEKS) (TEA, n.d.) include the study of ecosystems as essential topics of study. However, student achievement data reveal that as late as middle and high school, students do not have a good understanding of population and system dynamics (Grotzer & Basca, 2003).

Despite the curricular importance of food webs and system dynamics, many teachers lack sufficient literacy in ecology (Lambert, 2006, Payne & Zimmerman, 2010). Partial understanding and low confidence in teaching ecosystems suggests that teachers find this content area difficult to teach, possibly resulting in lessons that are teacher-directed and require limited thinking or problem-solving by the students. As with most topics, ecosystems and the interdependence of organisms can be taught using various tools and formats. Providing in-service and preservice teachers with alternative tools for teaching science topics is an important component of teacher education. As such, we developed the Peruvian Food Chain Jenga (PFCJ) as a tool to assist teachers with teaching ecosystem dynamics.

A possible way for teachers to help students understand the role of food chains in ecosystems is through the use of games. Games may be models or simulations of real complex systems (Gobert, 2005, Gobert et al., 2011), thereby helping students understand the interactive component of models. However, science teacher educators should not advocate games as a way to engage students unless the games have been shown to provide an equal or greater educational experience when compared with traditional instruction. Before the PFCJ can be fully introduced to teachers for implementation into the classroom, its effectiveness as an educational tool must first be understood through research. The aim of this study was to test the PFCJ as a multimodal educational tool that utilizes a game format to determine if it is a viable alternative for teaching the interdependence of organisms in a marine food chain and ecological content.

Literature Review

We present four bodies of research below. First, we provide a review of literature which addresses the ecology and food chain concepts related to our study. This literature explores the importance and difficulty of learning about the interdependence of organisms in an ecosystem. Next, we examine the literature focused on models because we are interested in a tool that modeled ecological interdependence utilizing a multimodal, game-like format. Third, we review literature on the modes through which meaning-making and communication occur, with an emphasis on modeling. Finally, we present the status of educational games because the tool we utilize the existing framework of the Jenga© game to manipulate a marine food chain.

Food Webs

The interdependent relationships in ecosystems are a disciplinary core idea outlined by the NGSS (NGSS Lead States, 2013) and the TEKS (TEA, n.d.) for students within several grade bands. For instance, students are expected to learn that food webs show relationships of animals that eat animals and animals that eat plants. This expectation seems simple at first, but ecosystems are complex networks that involve numerous variables, delicately balanced systems of causes and effects, and progressing structures which play out over time in ways that cannot be directly observed (Jacobson & Wilensky, 2006; Manz, 2012). Understanding how ecosystems work provides a foundation for learning about core scientific concepts, such as the theory of evolution and the theory of conservation of energy (Lehrer & Schauble, 2012).

Although educators consider food chains and food webs important topics, these subjects often accompany student misconceptions (Grotzer & Basca, 2003; Ozkan, Tekkaya, & Geban, 2004). Middle and high school students tend to think in terms of individuals and not populations, focus more on animals than on other organisms, and do not think about the community as a system (Grotzer & Basca, 2003). Furthermore, students show a limited understanding of ecosystem interactions, viewing the environment as a passive surrounding only functioning to provide resources (Lehrer & Schauble, 2012). Some students believe that disturbances in the food web depict unidirectional effects, shown by a deficiency in tracing multiple and extended ways in which the system could be disrupted (Hogan, 2000). For instance, students believe that modifications in one population may not affect another because they are too far apart within the food chain (Ozkan et al., 2004).

The marine and aquatic ecosystems have been neglected in K–12 science education despite their critical roles. Studies with a focus on education pertaining to aquatic and marine ecosystems have found a lack of knowledge and awareness of these ecosystems and their resources across the United States (Tran, Payne, & Whitley, 2010). Historically, the pictures in student textbooks have depicted food webs with arrows showing which organism was eaten as opposed to the direction of energy/matter flow (Schollum, 1983). More recent textbooks have been found to not always illustrate the complexity and interdependence of food chains and food webs (Beals, Krall, & Wymer, 2012; Lin & Hu, 2003; Songer, Kelcey, & Gotwals, 2009).

The study of food webs and food chains can support the practice and experience students need to look at the natural world as a complex, interrelated system. The inclusion of the ocean ecosystem in the curriculum has been found to promote student understanding of complex systems (Tran et al., 2010). Moreover, the study of food webs and chains offers solid opportunities for students to use, manipulate, and understand scientific models. Thus, teacher preparation programs should devote more attention to this topic. Teachers should acquire pedagogical and content knowledge that guarantees the support of student scientific thinking about marine food webs and food chains. They should be equipped to expose students to activities that promote personal interest and motivation to learn more about ocean ecosystems.

Scientific Models

Models have been used in meaning-making and the communication of scientific ideas for centuries. Models used for scientific teaching and representation include scale models, symbolic models, mathematical models, and theoretical models (Harrison & Treagust, 2000; Schwarz et al., 2009). Furthermore, models may be representations of

either static-external visualizations or dynamic systems (Biffi, Hartweg, Stewart, Patterson, Simanek, & Weinburgh, 2016a). Static-external visualizations are classified as diagrams and models, while dynamic systems are referred to as simulations (Gobert, 2005).

Dynamic scientific models serve as helpful tools that can be used by students to visualize scientific concepts, problematize or broaden understanding of a concept, develop a shared conceptual meaning of core ideas, predict scientific phenomena, and explore possible solutions (Manz, 2012). Even though models are used for many types of educational purposes, students pay more attention to them as objects to be interpreted, but not for the generation and testing of ideas (Lehrer & Schauble, 2006). The NGSS (NGSS Lead States, 2013) and the TEKS (TEA, n.d.) discuss the importance of using tangible models as a method to develop students' understandings of both the nature of the scientific enterprise and disciplinary core ideas.

Baek, Schwarz, Chen, Hokayem, and Zhan (2011) suggests that involving students in scientific modeling can play a vital role in helping them cultivate and evaluate explanations of the natural world. In selecting models to help students learn about ecosystems, it is important to find dynamic, modifiable structures that can be used to represent changes in the numerous variable of complex systems (de Ruiter, Wolters, Moore, & Winemiller, 2005). Grumbine (2012) reported that using colored Tinker Toys© as a modifiable structure to represent food-web concepts was an enjoyable activity for students, and useful in identifying students' conceptual understandings. The Jenga© tower is another such structure that can be utilized in the classroom to represent the complexities of environmental dynamics. De Ruiter et al. (2005) affirm that Jenga© towers may be beneficial over other models, such as the classic stone-arch metaphor, when representing food chains due to their ease of use and flexible structure that allows for modification by students.

Multimodal Representations

In recent years, science educators have researched many ways meaning-making and communication occur in science (Hand, McDermott, & Prain, 2016). Learning science can be considered multimodal since it requires students to connect different types of representations (Yore & Hand, 2010). Several views of multimodality have been offered. One representation is the hybrid language of science, which is composed of natural language, mathematical expressions, visual representations, and manual-technical operations (Lemke, 2004). Another representation describes the components as being "descriptive (verbal, graphic, tabular), experimental, mathematical, figurative (pictorial, analogous, metaphoric), and kinesthetic representations" (Murcia, 2010, p. 24). A third representation uses only two groups: descriptive (text, mathematical equations, logical phrases) and depictive (pictures, diagrams, graphics) (Gunel & Yesildag-Hasancebi, 2016). In each case, the components emphasize representation to facilitate the meaning-making process of scientific concepts.

Students often find difficulty in understanding the entire span of a given concept if they only view pictorial or textual representation (Bennett, 2011; Carolan, Prain, & Waldrip, 2008). However, combining multiple representation enables students to interpret the concept in different perspectives (diSessa, 2004; Hand et al., 2016; Tytler, Peterson, & Prain, 2006). When textual modes are supported with visual aids or figurative applications, students connect the scientific processes with the representations more meaningfully (Carney & Levin, 2002; Tippett, 2008). Additionally, "data reveal conclusively that meaning is made in all modes separately, and at the same time, that meaning is an effect of all the modes acting jointly" (Kress, Jewitt, Ogborn, & Tsatsarelis, 2001, p. 1). Each mode has its own function, having strengths and weaknesses in intelligibility, precision, and associative meaning, all necessary to move students toward more complex understandings.

There are several examples of multimodal applications in the literature. Biffi et al. (2016a, 2016b) describe the use of the Jenga© tower as a multimodal tool to represent the food chain of the Peruvian marine ecosystem. Additional examples include an interactive website to conduct virtual experiments about force and distance (Waldrip, Prain, & Carolan, 2006), a computer software to experience the spacing and moving of the particles (Waldrip & Prain, 2013), and a multimedia tool demonstrating the relationship between the Sun, Earth, and Moon (Brown, Murcia, & Hackling, 2013).

Games

Games are another a way to provide educational instruction. They may be fictional or representational and may serve as a model of the actual system. When used in educational setting, games result in positive learning outcomes (Mayo, 2007). Evidence indicates that games teach not only facts, but also reasoning that can be applied to real life situations (Mayo, 2007). As models of complex systems, games help clarify difficult issues and provide a context to complex thinking (Bochennek, Wittekindt, Zimmermann, & Klingebiel, 2007).

Research has also shown the personal changes that can occur among students as a result of games. In an early study involving gaming, four motivational components (attention,

relevance, confidence, and satisfaction) increase without affecting performance (Klein & Freitag, 1991). Later studies support the positive motivation in addition to advancing cognitive functions (Baines & Slutsky, 2009; Pinder, 2008). Barab and Dede (2007) found that games which involve collaborative work "may act as a catalyst for change in students' self-efficacy" (p. 3). Increased self-efficacy, the extent to which a person feels he/she can succeed in a given situation, has been positively associated with achievement and continued pursuit of science courses. Another outcome of using games in educational settings is a change in agency. Students become producers, rather than consumers, as they make choices with consequences. This does not typically happen in traditional instruction (Gee, 2003). Increased agency, rather than specific content knowledge, may be very important in changing students' environmental behaviors.

Theoretical Framework

Our research draws on Vygotsky's sociocultural constructivist theory (Vygotsky, 1978) and semiotic affordances (Bezemer & Kress, 2016; Lemke, 2000; Pickering, 2007) as the theoretical framework guiding our investigation into the effectiveness of the PFCJ. Vygotsky stresses the collaborative nature of learning, specifically the role of the "other." Others who are "more knowledgeable" serve as conduits for the tools of the culture, including language. When learners reach a cognitive level at which they are no longer able to progress without help, the more knowledgeable "other" has the task of offering guidance. This guidance may come as a provocative question, an answer to a question, or an additional resource. Interaction, itself a social endeavor, helps the learner reach a higher level of understanding than would be possible without guidance. This theory supports having students work in small groups as they share ideas and act as peer tutors. Vygotsky's theory of learning also includes the role of cultural signs as tools for learning. This theory on the use of cultural signs highlights the importance of learning to use the words, sentence structure, and physical tools of a discipline.

Semiotics, the study of symbols in meaning-making and communication, is important in connection with multimodal research. Human beings use a wide range of semiotic resources, often simultaneously, to provide access to similar messages in different ways. Non-linguistic systems work with linguistic systems to afford the student collection of communication tools (Bezemer & Kress, 2016; Hammond & Gibbons, 2005). Multiple research groups examine the link between science activity (multimodal) and meaning-making (Tang, Tan, & Yeo, 2011; Waldrip et al., 2006). Additional research highlights the benefits of using multimodal tools for teaching science (Gillen, Littleton, Twiner, Staarman, & Mercer, 2007).

Methods

The PFCJ, a multimodal educational tool, was developed as an alternative way to engage upper elementary students in a lesson on food chains. A detailed explanation of how the model was designed to be used in the classroom has been described by Biffi et al. (2016a). After developing the educational tool, we conducted a validity study of the PFCJ to determine its appropriateness for use with classroom students (Biffi, Hartweg, de la Fuente, Patterson, Stewart, Patterson, Simanek, & Weinburgh, 2016b). Feedback received from the students indicated that the design of the PFCJ met its desired objectives of (a) being "kid-friendly," (b) demonstrating the value of scientific models, (c) providing content in an interesting format, and (d) using evidence to construct arguments for cause and effect. The classroom teacher also found the PFCJ to be an effective, easy-to-use teaching model for her students. In response to questions that arose during the validity study (Biffi et al., 2016b), we continued our research to evaluate the PFCJ for its impact on student learning through a pilot study. Particularly, we were interested in using a mixed-methods approach (Creswell, 2003; Creswell & Plano Clark, 2011). A concurrent nested design was used to seek information beyond the main research question (#1). This method gave priority to one method (for us, the standard content test) while embedding a method of hearing student voices.

The research team for the pilot study consisted of seven science education graduate students and a science education professor. All members of the team met regularly to plan the research, develop the assessments, collect data, and conduct analysis.

Research Questions

The research presented here focuses on the experience of two sets of students during a lesson on a marine ecosystem. The research purpose was to use a coarse-grain approach to determine if fine-grain research on the use of the tool is warranted. More specifically, we tested the idea that one multimodal experience with the PFCJ is as beneficial as one traditional lesson on student learning. by asking the following questions:

(1) What is the quantitative difference in:
   a. postinstruction achievement scores between the control and experimental groups of 5th-grade students?
   b. gain from pretest to posttest between the control and experimental groups of 5th-grade students?

(2) What, if any, are the qualitative differences found on the "What I Did/What I Learned" inventory between the control and experimental for 5th-grade students?

Intervention

We created two lessons having the same objectives and the same features, but using different instructional formats. Both control and experimental groups used the Introductory Video, Event Cards, and Guide Sheet as outlined in Biffi et al., (2016b). These components comprised a well-planned lesson, which presented the concepts of scientific models, food chains, and keystone species.

The two lessons began to differ after completing the Guide Sheet. Students in the control group were given a handout with a chart that contained a predetermined number of individuals for each species of the food chain. The chart had space for students to record the new number of individuals after each "move." Students then drew an Event Card, discussed what effect the situation would have on the food chain, and recorded the decision on the chart by adding or subtracting individuals of one or more of the species. When any population reached zero, students stopped and talked within the group about the results.

For the experimental group, students participated in the same lesson with one modification. Instead of a chart, they built a wooden tower to model the food chain. This group used the same Event Cards, but rather than add or subtract individuals from the food chain, they removed or added the appropriate blocks labeled with stickers indicating the trophic level. When the tower fell due to becoming too fragile, the students discussed their results. The alternative lesson had all the components found in the more traditional lesson, but with the inclusion of the use of the multimodal tool that modeled a food chain.

Participants

For this pilot study, we selected a public charter school within the Dallas/Fort Worth Metroplex. The 413 students enrolled in the school were predominately Hispanic (71%) and economically disadvantaged (71%). Twenty-six percent of the students were classified as English language learners. All 71 students in the 5th grade were asked to participate in the study and were provided with informed consent forms. Data were collected from 54 students with signed consents; however, due to the limited sample size, specific demographic information was not collected. Twenty-eight students were assigned to the control group, while 26 students were assigned to the experimental group.

Data Collection

The research team prepared an 11-item multiple-choice assessment using released content questions from the state's science exams. In addition, the research team developed items based around the multimodality and sociocultural constructivist nature of the intervention to cover the modeling, food chain and food-web concepts, and cause-effect relationships. A science educator and scientist reviewed the assessment to provide content validation, and two elementary teachers reviewed it for readability.

During the third week of August (2015–2016 school year), the preintervention assessment was given to all the 5th-grade student participants. Students in periods 1, 3, and 5 were assigned to be the control group, and periods 2, 4, and 6 were assigned to be the experimental group. All lessons were taught by a trained, science education graduate student. Immediately after each lesson, the 5th-grade students were asked to complete a "What I did/What I learned" inventory. On this inventory, students were asked to write descriptions of the process they used and the concepts they learned as a result. Two weeks after the lesson, the 5th-grade students completed a delayed posttest composed of the same questions as in the pretest. Consistent with embedded experimental design methodology (Creswell & Plano Clark, 2011), this approach provided qualitative data during the intervention with quantitative data collected preintervention/postintervention.

Data Analysis

Quantitative data were collected because this is the method used by schools to assess the progress of students. The multiple-choice content assessment was graded, and students received 1 point for each correct answer. The four open-ended questions were scored on a 0–3 scale, using a rubric developed by the team (Webb, Herman, & Webb, 2007). Scores on the pretest and posttest were entered into SPSS (v. 20). The assumption that there was no difference between the preintervention experimental and control group was tested using a *t*-test. We then used a *t*-test to compare the postexperimental test scores to the control group test scores and a paired *t*-test to compare each student's preexperimental and postexperimental test scores.

Qualitative data were collected in order to discover nuanced differences in the two groups. Responses from "What I Did/What I Learned" were coded using two characteristic methods of grounded theory, initial coding, and axial coding (Saldaña, 2011). During the first cycle of coding, preliminary codes were assigned to students' responses (focus on the text) by each research team member independently. This process produced a list of first level

Table 1
Summary Statistics for Student Scores

Group		Mean	*N*	*SD*	SE
Control	Pre	13.21	28	5.672	1.072
	Post	16.25	28	6.186	1.169
Experimental	Pre	12.19	26	4.382	0.859
	Post	14.19	26	4.364	0.856

concepts. The team met, compared codes, and agreed on the codes to move into cycle two. In the second and subsequent cycles of analysis, the team coded together. During this process, the provisional codes (focus on the concepts) were grouped, sorted, and relabeled. Eventually, the salient codes were assigned by group consensus. Trustworthiness was established through credibility, confirmability, and transferability. The process of individual coding followed by group discussion and consensus established credibility and confirmability, whereas, the rich descriptions used in the results section provides transferability.

Findings

The PFCJ addresses an important content topic often found on student achievement assessments. Food chains and webs have been suggested as a way of introducing students to the system concept, by reflecting on energy flows or population changes (Hogan, 2000). Additionally, researchers have pointed out that it is important to analyze the complex nature of food webs when teaching ecosystem principles (Karamanos et al., 2012). Thus, both systematic thinking and ecosystem content can be taught as part of the same lesson on food chains. Having used a mixed-methods design, our findings will first present the quantitative data followed by the qualitative data, with discussion of the implications immediately following each question.

Quantitative Data

In response to research question 1a, "What is the quantitative difference in postinstruction achievement scores between the control and experimental groups of 5th-grade students?" the comparison of the posttest scores of both groups brought the following results. There was no statistically significant difference between the scores of the posttest of the control (16.25 ± 6.186 points) and experimental group (14.19 ± 4.364 points), $t(52) = 1.402$, $p = 0.167$ (Table 1). This indicates that both experimental and control groups ended the unit with approximately the same content when assessed by our standard content test.

In response to research question 1b, "What is the quantitative difference in gain from pretest to posttest scores between the control and experimental groups of 5th-grade students?" the comparison of the scores of both groups brought the following results. In a comparison of paired-samples *t*-test between the pretest and posttest of each group, we found a highly significant difference between the pretest/posttest scores in both the control ($t(27) = -3.457$, $p = 0.002$) and the experimental group ($t(25) = -2.733$, $p = 0.011$) (Table 2). In the experimental group, there was a mean increase of 2.00 points in correctly answered questions between the experimental group's pretest and posttest scores. Thus, the two lessons produced an increase in content knowledge about scientific models, food chains, and keystone species.

Discussion. These results demonstrate that 5th-grade students do equally well on the content-based assessment when a well-planned traditional approach and the multimodal game-format approach are used. This is understandable as both sets of students utilized the same Event Cards (presenting content) and discussed the ideas in small groups. The difference was in manipulating the dynamic model, which utilized blocks and allowed students to see the tower become fragile and eventually collapse as populations were reduced. The results from the study indicate that the alternative lesson (PFCJ) did not interfere with student achievement and is, therefore, appropriate to use as an alternative to a traditional lesson.

The PFCJ also addresses the issue of engaging students in experiences where they use and construct models as a way of presenting ideas and explanations which are important components of the most current science teaching standards (NGSS Lead States, 2013; TEA, n.d.). Because food chains and the connectedness of species within an ecosystem are complex in nature, utilizing dynamic models may be an alternative way of teaching the topic. PFCJ uses food webs as a model and the Event Cards with content as a springboard for constructing ideas about ecosystems.

Table 2
Paired-Samples Statistics for the Control and Experimental Group

Group	Average of Mean Differences	*N*	*SD*	*t*-Value	df	Two-Tailed sig.
Control	3.04	28	5.672	−3.457	27	0.002
Experimental	2.00	26	3.731	−2.733	25	0.011

Qualitative Data

In response to research question 2, "What, if any, are the qualitative differences found on the "What I did/What I learned" inventory between the control and experimental groups of 5th-grade students?" student responses to the inventory were qualitatively coded between both groups, which brought the following results. Two major themes emerged: awareness and connectedness. Both themes were evident in the control and experimental groups, however, there were differences in the frequency themes and subthemes between the two groups.

Awareness. The awareness theme had two subthemes, which were human impact and endangered species. Both groups of students gave examples of having gained an awareness of human impact. A few students in the control group also included the idea of having a new awareness about endangered species. For example, a student in the control group wrote "I learned what the populations could turn out to be like in the [future]. I learned that the animals are in danger and could decrease at any time in the world and be extinct."

Connectedness. The students who wrote about connectedness either demonstrated an understanding of the complex, holistic nature of the food chain, or the less complex predator–prey relationship. Although both groups mentioned connectedness, this theme was much more prevalent in the experimental group than in the control group. Students who were engaged in building the tower and watched it become unstable and eventually collapse due to different events, used language that indicates a more sophisticated understanding of the connectedness and interdependence of the species at twice the rate of control. As an example of connectedness, one student from the experimental group wrote: "I learned about the food chain. Also that all species depend on others to eat. A food chain starts when a small animal or plants gets eaten." The control group did not appear to grasp the holistic connected nature of the food chain at the same level that was evident in the experimental group. To illustrate these ideas, examples of the themes are provided in Table 3.

Table 3
Themes Discovered in "What I Did/What I Learned" Inventory

Theme	Examples
Awareness	
Subtheme: Human impact	"I learned that the more species we kill the food chain will run out of food." "I learned that a plastic kills animals."
Subtheme: Endangered species	"I learned what the populations could turn out to be like in the featur *[sic]*. I learned that the animals are indanger *[sic]* and could decrease at any time in the world and be extinct. I learned that adding and substracting *[sic]* will be in my life even when I'm doing science. I learned there are animals that need help all over the world because they are getting murderd *[sic]* and they decreases the population in the animals life."
Connectedness	
Subtheme: Predator–prey	"I realized the more the top pradators *[sic]* decreased the bottom predadors *[sic]* increased"
Subtheme: Holistic	"Animals depend on each other. If one dies it affects everything." "When one animal or species extinct, the whole life cycle will distrupt *[sic]*." "I learned that it is important to take care of things because animals need to eat and they eat another and pass it on and if you don't have what they eat they will die and also the other animals and pass it on."

Discussion. The results from the elementary students' written responses are especially interesting to educators when focusing on environmental issues. Both the experimental and control groups indicated that they now have a new awareness of human impact and endangered species. Issues like microplastics or ghost fishing, introduced to students in the Event Cards, promoted responses like "I learned that a plastic kills animals." Having an instructional tool that has been shown to leave students aware of the human impacts to the ecosystem is important. The U.S. Environmental Protection Agency (EPA) recognizes public awareness as a main component of environmental education, which results in enhancing individuals' "skills to make informed decisions and take responsible action" (EPA, 2016, para. 1). We believe the Event Cards, which presented both groups with content, attributed to this awareness.

The most enlightening outcome was that the experimental group was qualitatively different from the control group in regard to the level of connectedness they expressed in their writings. The two subthemes of understanding of the complex holistic nature of a food chain and the less complex predator–prey relationship were stated by the experimental group. We attribute this additional and important understanding of system complexities to having witnessed the fragility of the tower. Unlike the control group, these students witnessed their model becoming unstable and falling apart as event cards provided situations that stressed the trophic levels. The PFCJ model helped solidify the understanding of

ecosystem connectedness in a way that the traditional instruction did not. These findings support the research from de Ruiter et al. (2005) that suggest the modifiable structure of the Jenga© tower can serve as an effective tool to represent changes in the numerous variables present in complex systems. Since prior research has shown that students have trouble understanding the interactions within ecosystems (Lehrer & Schauble, 2012), we think our findings indicate that the PFCJ may be an effective educational tool to use in the classroom when teaching ecosystems.

Conclusions

Our findings allow us to conclude that using a model such as PFCJ as a means of teaching and connecting scientific content with practices related to ecosystems is an effective method of engaging students in intelligent discussions about these topics. By promoting group debate and discourse about events and matters of scientific concern, PFCJ offered richness and excitement of learning about the natural world as well as rigorous content on critical environmental issues, and aided students in understanding the interconnectedness present in ecosystems.

As teacher educators, we know that in many countries a major emphasis is placed on how to improve student achievement. However, in addition to student achievement, cognitive processes (i.e., critical thinking, synthesis, and analysis) and working in teams are being fore fronted as 21st century skills. Therefore, in teacher preparation and professional development, we advocate teaching strategies that include using real-world events that have the potential to increase achievement, critical thinking, attitudes, and other student outcomes. However, before new strategies are provided to teachers, it is important to verify their effectiveness in the classroom. This pilot study serves as a critical step towards the development of the PFCJ as a tool to be used in future teacher development programs.

As educational researchers, we understand how important it is to connect research with practice in the field of education. Consequently, our study contributes to the field of science teacher education by presenting a Jenga© multimodal tool that aligns with the 5th-grade TEKS (5.3 critical thinking and scientific problem-solving; 5.9. Organisms and environments) and NGSS for disciplinary core concepts (LS2: Ecosystems) and crosscutting concepts (systems) as a way to model a marine ecosystem for upper elementary students.

We consider our model a viable alternative way for teaching the interdependence of organisms in their environment. The alternative lesson we offer takes equal time as the traditional lesson and is not expensive. The materials necessary to prepare this lesson have been outlined in Science Scope (Biffi et al., 2016a) and can be easily obtained by science teacher educators.

Limitations and Areas of Future Research

This pilot study contains limitations that may be addressed in future studies. First, this study was conducted with a limited sample size from a single grade level and school. Due to the limited size, specific demographic data of students was not collected during the study. Increased sample size and demographic data may provide additional insight in regards to the effectiveness of the PFCJ as an educational tool for subsets of students. Another major limitation is the duration of the intervention. The intervention occurred over a single lesson. While one lesson is often all that a teacher is able to give to the topic of food chains, future research may focus on the effectiveness of the PFCJ after multiple uses. Additionally, data collection was limited to student achievement tests and the analysis of "What I Did/What I Learned" inventory after the completion of the lesson. Discourse analysis of student conversations during the lesson could reveal nuanced differences that the written responses lost. With the positive results of the presented pilot study, the research team has designed future studies to examine the effectiveness of this tool in different settings.

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Middle School Mathematics Teachers' Perceptions of the Common Core State Standards for Mathematics and Its Impact on the Instructional Environment

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This study examines Middle School Mathematics Teachers' (MSMTs') (N = 1,241) perceptions of the Common Core State Standards for Mathematics (CCSSM) and its impact on the instructional environment. A total of eight factors appear in the data. These factors include professional support, teachers' use of district-adopted and non-district-adopted curricular resources, influence of CCSSM assessment and teacher evaluation on the instructional environment, influence of the CCSSM on classroom instruction, teachers' planning practices, and perceived rigor of the CCSSM. The data suggest that teachers' use of digital resources located online was disconnected from their district-adopted resources suggesting a lack of curricular coherence. MSMTs note that the CCSSM had caused them to incorporate more reform-oriented practices such as exploration and productive struggle into their daily instruction. MSMTs also perceive that the CCSSM includes new content that is more rigorous than previous state standards. Sampled MSMTs state that while state assessments will measure CCSSM content, they are less likely to include more complex problems or the standards for mathematical practice. Teachers are more likely to read teacher resources than student textbook activities online and to use digital resources for remediation instead of inquiry activities. Over one-third of MSMTs wanted more CCSSM professional development.

For the first time in the history of the school mathematics education system in the United States, the majority of school students are under the umbrella of influence of one set of standards, the Common Core State Standards for Mathematics (CCSSM). The effects of the CCSSM are further magnified due to required assessments and the subsequent connection of these assessments to teacher evaluation (Duncan, 2009a, 2009b). Middle school mathematics teachers (MSMTs) are especially under increased pressure, as they are required to test students annually in Grades 6 through 8 on assessments aligned with the CCSSM. Furthermore, research conducted by Reys, Dougherty, Olson, and Thomas (2012) suggests that there are important differences between CCSSM middle school content standards and previous state curriculum frameworks. While a number of studies have been conducted on teachers' perceptions of the CCSSM (e.g., Hart Research Associates, 2013) these results are not often disaggregated at the middle school level. Additionally, previous research has only superficially examined teachers' perceptions of the Standards for Mathematical Practice (SMPs) (Perry et al., 2015) or the connections between the CCSSM and teachers' curricular resources (Scholastic, 2013). For these reasons, this study reveals the underlying structure of a large sample of MSMTs' ($N = 1,241$) perceptions of the CCSSM and its impact on the instructional environment.

Background

Changes in the CCSSM

In their review of the influence of teaching on students' learning, Hiebert and Grouws (2007) note that research suggests that opportunity to learn is an important necessary condition for student learning. Moreover, the focus of school mathematics instruction has often been broken down into two categories: teaching for skill efficiency and teaching for conceptual understanding. Recitation has been the predominant form of teaching in the United States and in school mathematics classroom this instruction has focused on skill efficiency (Stigler & Hiebert, 1999). Hiebert and Grouws note two features of teaching that promote conceptual understanding: teachers and students attend explicitly to concepts and students struggle with important mathematics. These features are connected to the CCSSM. For instance, McCallum, one of the architects of the CCSSM, writes that conceptual understanding is one of the components of rigor in the CCSSM (2012) along with procedural fluency and meaningful applications. The

importance of students persevering through struggles in solving problems appears as a habit of mathematically proficient students in the SMPs (Common Core State Standards Initiative, 2010; McCallum, 2012).

Research suggests that the CCSSM is different from previous state mathematics standards (Porter, McMaken, Hwang, & Yang, 2011; Reys et al., 2012). Specifically, Reys et al. (2012) found that content appearing at the high school level in previous state standards now appeared at the middle school level while Porter et al. found low alignment between the CCSSM and previous state standards in terms of mathematics content as well as cognitive demand. Schmidt and Houang (2012) found the CCSSM to be very similar to the curriculum standards used by countries that were considered to be high achieving on the Third International Mathematics and Science Study administered in 1995. They also found that state standards that were used before the advent of the CCSSM were found to be less similar to standards from these high-achieving countries. Additionally, state standards that were more similar to the CCSSM performed better on the 2009 Grade 8 National Assessment of Educational Progress. Cobb and Jackson (2011) found the CCSSM to be focused in that different components of important mathematical ideas were addressed over time. In terms of quality, they found the CCSSM to have what Bruner (1987) termed "clout" due to their emphasis on applying mathematics to contexts outside of school mathematics within the content standards as well as the modeling SMP. Cobb and Jackson also used coherency to evaluate the quality of the CCSSM and agree with the work by Confrey, Maloney, and Nguyen (2010) showing how learning progressions build students' understanding of central mathematical ideas across grades. Cobb and Jackson emphasize, however, that the successful implementation of the CCSSM will depend on the willingness of schools and districts to dedicate professional development to helping teachers understand and enact instruction around key mathematical ideas over time as opposed to instruction focused on disparate collections of procedures, which has characterized mathematics instruction in the past (Stigler & Hiebert, 1999).

Teacher Preparation to Teach the CCSSM

Despite the differences between CCSSM and teachers' practices as well as the differences between CCSSM and previous state standards (Porter et al., 2011), the percentage of teachers feeling well prepared to teach CCSSM vary from 72 (Cogan, Schmidt, & Houang, 2013) to 93% (Davis, Choppin, Roth McDuffie, & Drake, 2013). However, K–12 teachers working in urban districts feel less prepared to teach the CCSSM than teachers who do not work in urban districts (51–63%, $N = 800$) (Hart Research Associates, 2013). In a similar vein, only 50% of teachers working with low socioeconomic status students felt very or fairly prepared to teach the CCSS compared to 64% of teachers working with predominantly high SES students (Hart Research Associates). Teachers' preparedness levels also vary when teachers are asked about other student groups such as English-language learners (Education Week Research Center [EWRC], 2013; Perry et al., 2015). For instance, 29% of teachers ($N = 375$) surveyed did not feel at all prepared to teach the CCSS to English-language learners (EWRC, 2013). Overall, teachers feel prepared to teach the CCSS or CCSSM, but this level of preparedness varied by school location as well as when the focus of that instruction involves particular student groups such as English-language learners. Previous research has found that teachers perceive that the CCSSM has had a number of effects on their instruction that is aligned with reform-oriented principles (National Council of Teachers of Mathematics [NCTM], 2014). For instance, the majority of MSMTs stated that the CCSSM would cause them to teach more conceptually, incorporate more opportunities for students to explore mathematical ideas, solve more complex problems, and emphasize more mathematical communication with their students (Choppin, Davis, Drake, & Roth McDuffie, 2013; Davis et al., 2013).

In 2011, as Common Core implementation was just underway, teachers identified a need for professional development to prepare for the CCSSM (Cogan et al., 2013). During the five years since the adoption of the CCSS, teachers have received professional development around these standards (EPE Research Center, 2013). For instance, in a survey of 591 classroom teachers in 2013, 24% of respondents had spent two–three days, 17% of respondents had spent four–five days, and 41% of respondents had spent more than five days on professional development connected to the CCSS. The topics and percentages of teachers experiencing that professional development were as follows: CCSSM (55%); alignment between the CCSS and previous state standards (53%); curriculum resources and materials (42%); CCSS-aligned assessments (23%); and teaching CCSS to specific student groups (15%). A recurring theme across these surveys is that while teachers have received professional development, about a third would like additional professional development in order to feel better prepared to teach the CCSS (Choppin et al., 2013; Cogan et al., 2013; EPE Research Center, 2013).

Teacher Perceptions of CCSSM Assessment and Evaluation

Overall, teachers reported a lack of familiarity with the Common Core-aligned assessments (EPE Research Center,

2013; EWRC, 2013; Scholastic, 2013, 2014). Accordingly, teachers expressed an interest in professional development focusing on the content of these assessments (EPE Research Center, 2013; Perry et al., 2015; Scholastic, 2013). Despite this lack of information teachers professed faith that these assessments will measure the CCSSM content standards and SMPs and stated that the Common Core-aligned assessments will influence their own instructional practices and classroom assessments (Choppin et al., 2013).

As mentioned earlier, the impact of the CCSSM is magnified due to the connection of student achievement to teacher evaluation. Teachers were aware of this increased emphasis of student test scores on teacher evaluation and that majority of teachers state that these policies have influenced their instructional decisions and assessment practices (Choppin et al., 2013). Indeed, in 2015, a total of 17 states included student growth as a preponderant criterion in evaluating teachers and 18 other states included student growth as a significant criterion in teacher evaluations (Doherty & Jacobs, 2015).

Teachers' Perceptions of Curriculum Alignment to the CCSSM

Due to the important role that textbooks play in mathematics education (Banilower et al., 2013), surveys have examined the connection between curricular resources and the CCSS or CCSSM. Researchers have found a lack of alignment between curriculum materials that are advertised as aligned with the CCSSM and the CCSSM (Center for the Study of Curriculum, 2015; Polikoff, 2015). Teachers also perceived the curriculum resources that they currently use as lacking alignment with the CCSS (EPE Research Center, 2013; EWRC, 2013; Scholastic, 2013, 2014) or the CCSSM (Roth McDuffie et al., 2017). Moreover, teachers did not feel that districts provide them with the resources they needed to align their instruction to the CCSSM, nor did they feel that their districts have an effective process in place to determine whether supplemental curriculum materials are needed or changes need to be made to supplemental materials (Perry et al., 2015). Additionally, teachers did not feel that their curriculum materials enable them to help students with disabilities learn the content and practices embedded in the CCSSM (Perry et al., 2015).

The survey at the center of this study builds on previous national surveys conducted by other groups (e.g., Education Week) as well as those conducted by our group (e.g., Davis, Choppin, Drake, & McDuffie, 2014) by focusing on the CCSSM, examining other components related to MSMTs' instructional practices, and by presenting results from a larger sample size. In contrast, most surveys on teachers' perceptions have focused on the CCSS in general and have included teachers working across grades K–12. The survey on which we are reporting in this article focuses on MSMTs and provides more current insights into this important group's perceptions with regard to the CCSSM and their instructional environment. Specifically, this study was designed to answer the following research questions:

(1) What is the structure underpinning MSMTs' perceptions of the CCSSM and its impact on the instructional environment?

(2) How does a sample of MSMTs perceive the CCSSM and the instructional environment given the identified structure?

Methods

Sample

Market Data Retrieval (MDR) administered the survey nationally during May–June 2015. A total of 1,241 teachers working in 39 out of the 42 CCSSM states completed the survey. These teachers taught middle school students in grades 6, 7, or 8 and were predominantly female (Male = 304 [24.5%], Female = 935 [75.3%]). The majority of teachers considered mathematics to be their primary teaching certification/responsibility ($N = 1,086$ [87.5%]). The percentages of MSMTs working at different types of schools are as follows: Urban (18%), Rural (30.3%), Suburban (39.5%), and Town (12.2%). Nearly half of the MSMTs in our sample taught in schools that were categorized as having 50% or more of their students received free or reduced-price lunch. It is important to note that while we cannot claim a representative sample on a national level, the sample does contain characteristics that are similar to MSMTs in the United States. For instance, the majority of MSMTs in the United States are female (Feistritzer, 2011). The percentage of elementary and secondary schools in the United States in 2010–2011 that were categorized as urban, suburban, town, and rural were 26%, 27%, 14%, and 32%, respectively (Kena et al., 2015). The percentage of teachers teaching at town and rural schools was similar to national percentages while our sample of teachers working at urban and suburban schools was different. Urban teachers were underrepresented in our survey (26% vs. 18%) while suburban teachers were overrepresented (27% vs. 39.5%). The percentages of MSMTs sampled working at schools with different percentages of students eligible for free or reduced-price lunches were similar to the percentages of students at U.S. public schools. For instance, nationally 44% of public schools have 0–50% of their students receiving free or

reduced-price lunch (Kena et al., 2015), as compared with 49.4% in our sample.

Survey Design

Given the analyses conducted by Reys et al. (2012) regarding the differences between previous state curriculum frameworks and the CCSSM, we inserted questions in the survey to examine teachers' perceptions involving CCSSM content at the middle school level. The specific inclusion of rigor in the CCSSM (McCallum, 2012) led us to include questions in the survey to examine teachers' perceptions of rigor in the CCSSM. We built on previous surveys (e.g., Cogan et al., 2013; EPE Research Center, 2013) by including questions involving teachers' familiarity with and preparedness to teach the CCSSM. With the differences between CCSSM and previous state curriculum frameworks (Porter et al., 2011; Schmidt & Houang, 2012), we were interested in whether teachers perceived that these new standards, especially components of the SMPs, had indeed impacted their instruction. Given the important role that district-adopted curricular resources play in classroom instruction (e.g., Tarr et al., 2008), we were interested in teachers' perceptions of the connections between their curricular resources and the CCSSM. Interviews with MSMTs suggested that assessment and evaluation associated with the CCSSM were concerns of teachers (Roth McDuffie et al., 2017). These findings resulted in the inclusion of a set of questions examining teachers' perceptions about CCSSM-related assessment and the connection of teacher evaluation to student achievement on CCSSM-related assessments.

The increase in digital book sales as well as the fact that many states have changed their definitions of textbooks to include digital resources (Fletcher, Schaffhauser, & Levin, 2012) led us to include questions asking teachers about their use of digital textbook resources that were part of their primary district-adopted textbooks and those that were not. The important role that teacher planning plays in the classroom environment and students' learning opportunities led to the inclusion of questions related to planning in the survey (Clark & Peterson, 1986; Stigler & Hiebert, 1999). We were interested in the role of the CCSSM in planning as well as teachers' use of student work in their planning as the latter has been found to be an important component of professional learning communities that lead to positive influence on teachers and students (Fulton & Britton, 2011). Altogether this survey was designed to measure teachers' perceptions of the CCSSM and its impact on the instructional environment.

Analysis

Descriptive analyses involved the enumeration of different categories and calculations of percentages on Likert-type questions. The percentages of MSMTs strongly agreeing or agreeing were combined for reporting purposes. The percentages of MSMTs choosing the categories of moderately or extensively in questions involving digital/electronic resources were combined and reported. Questions involving MSMTs' use of curriculum materials in planning contained five different categories. We decided that once or twice a week and almost every day represented frequent use of these documents for planning purposes and collapsed these two categories into one and reported these percentages.

Field (2009) describes three purposes for conducting a factor analysis: (a) to reduce the size of a data set; (b) to develop a survey to measure a variable underlying the data; and (c) to identify the structure of one or more variables. As described earlier, the purpose of the factor analysis conducted for this study is to identify the structure of teachers' perceptions of the CCSSM and its impact on the instructional environment. As an initial step in conducting a principal components analysis (PCA) the correlation matrix among 51 variables was produced. Two variables had no correlations of at least absolute value .3 or greater. These two variables were eliminated and two other questions were removed due to their similarity to other survey questions leaving 47 variables included in the PCA. Given the connection of standards to teachers' instructional environments, we suspected that factors were correlated with one another, so we used oblique rotation (oblimin). A Scree Plot is preferable to Kaiser's criterion for determining the number of factors to extract (Field, 2009). The inflection point in the Scree plot suggested the presence of between five and eleven factors underlying the data set. We examined extractions beginning at five factors and steadily increased the number of factors extracted until we had well-defined factors that explained more than 50% of the variability of the data. These criteria were met with eight factors extracted. The Kaiser-Meyer-Olkin measure verified the sampling adequacy of the analysis, KMO = .853. In addition, all of the KMO values were above .7, above the accepted limit of .5 (Field, 2009). Bartlett's test of sphericity $\chi^2(1,081)=25,386.71$, $p < .001$ suggested that correlations between items was of sufficient size to permit PCA. These eight factors accounted for 55% of the variability of the data. Cronbach's Alpha was used to measure the reliability of each of the eight factors. The reliability of the factors was considered to be good as they ranged from .70 to .92 (Field, 2009).

Results

The factor analysis appears first and is organized by presenting each factor in decreasing level of variability

Table 1
Perceptions Surrounding Professional Support

Survey Item	Percentage Agree or Strongly Agree
You are familiar with the SMPs described in the CCSSM.	94.5%
You are familiar with the mathematical content standards in the CCSSM for the grade levels you teach.	97.2%
You are familiar with Mathematical Content Standards in the CCSSM for grade level(s) other than the grade level(s) you are currently teaching.	81.5%
You are well prepared to teach with the CCSSM.	79.9%
Your district has encouraged or supported you to try new instructional approaches as a result of the implementation of the CCSSM.	85.4%
Your district has provided you with adequate professional development around the CCSSM.	63.5%
You have collaborated with teachers from other districts to better understand how to supplement the CCSSM.	50.6%

explained. The percentage of MSMTs agreeing or strongly agreeing with each of the survey items associated with a particular factor appears within that factor's description.

Factor Analysis

The factor loadings after rotation appear in the Appendix. The first factor, Professional Support, consisted of seven survey items and explained 16.0% of the variance in the sample. This factor illustrates the many tendrils emanating from support that extend into other areas associated with the CCSSM and teachers' instructional environments. For instance, professional development was connected to teachers' familiarity with the CCSSM process and content standards as well as their perceptions of their preparedness with respect to the CCSSM. This factor also included teachers' collaborations with their colleagues from other districts as well as their perceptions of their district's support for new instructional approaches.

The descriptives for this factor appear in Table 1. Although MSMTs are familiar with CCSSM content and SMPs, a somewhat lower percentage of MSMTs felt well prepared to teach the CCSSM. Table 1 also shows that just barely half of the MSMTs surveyed collaborated with teachers from other districts in understanding the CCSSM. The majority of MSMTs report that their school districts have encouraged new instructional approaches. One-third of MSMTs surveyed noted that they had not received adequate professional development around the CCSSM.

The second factor, Teachers' Use and Reading of Non-District-Adopted Digital/Electronic Resources, extracted from the data consisted of five survey items and accounted for 9.3% of survey variability. The majority of items in this category were composed of teachers' perceptions of their reading and use of digital/electronic resources from resources that were not connected with their district-adopted curriculum resources. Interestingly, these resources were not connected to any of the survey items associated with teachers' district-adopted curricula. As seen in Table 2 MSMTs were more likely to use these digital resources for remediation than inquiry and they were more likely to consult the teacher resource versions of these resources than the resources intended strictly for students.

The third factor, Influence of CCSSM Assessment and Teacher Evaluation on the Classroom Environment, consisted of five survey items and explained 7.1% of the variance. These items consisted of teachers' perceptions of the influence of CCSSM-aligned assessment and teacher evaluation on instructional decisions, assessment practices and content/practices emphasized during classroom instruction. In addition, an item connecting CCSSM-related assessment and teacher evaluation was a component of this factor. The appearance of assessment and teacher evaluation as one of the top factors speaks to the importance of these CCSSM-related policy components for teachers.

Table 2
Teachers' Use and Reading of Non-District-Adopted Digital/Electronic Resources

Item	Moderate/Extensive Use
Read digital/electronic student text pages or worksheets	50.6%
Read digital/electronic teacher resources	63.1%
Use digital/electronic resources to plan primary activities for your lessons	64.5%
Use digital/electronic resources to create supplemental activities for practice or remediation	70.7%
Use digital/electronic resources to create inquiry-based activities	57.2%

Table 3
Influence of CCSSM Assessment and Teacher Evaluation on the Classroom Environment

Item	Percentage Agree or Strongly Agree
Increased emphasis on student test scores in the evaluation of teachers.	71.7%
The teacher evaluation process in your state/district influences your instructional decisions.	69.2%
The teacher evaluation process in your state/district influences your assessment practices.	65.6%
State assessments will influence your assessment practices.	77.7%
State assessments will help you decide what CCSSM mathematics content and practices to emphasize.	66.8%

Table 3 shows the descriptives associated with the third factor. A majority of MSMTs has noticed the increased emphasis on student test scores in teacher evaluation. Although the MSMTs recognized this emphasis, a slightly smaller majority noted the influences of teacher evaluation on instructional decisions and assessment practices. The results in Table 3 also illustrate the strong effect that the CCSSM-aligned assessments have on teachers' assessment and instructional practices. For example, over three-fourths of the MSMTs sampled agreed or strongly agreed that the state assessments will influence their own assessment practices.

The fourth factor, Influence of the CCSSM on Classroom Instruction vis-à-vis Previous State Standards, extracted from the data comprised eight survey questions and accounted for 6.3% of the variance in participant survey responses. This factor included items that indicated how the CCSSM had influenced teachers' instructional practices. These practices consisted of mathematical processes such as communication and exploration, content such as concepts and procedures, and opportunities for students to struggle in mathematics. In addition, this category included change in classroom instruction in general as well as the influence of the CCSSM on how teachers use classroom materials.

Table 4 shows the questions associated with MSMTs' perceptions of the influence of the CCSSM on their daily instructional practices. MSMTs perceived changes to their classroom instruction that are aligned with reform-oriented techniques (NCTM, 2014) such as communication and exploration. Similar to past surveys of MSMTs' perceptions of the CCSSM (Davis et al., 2013) teachers in this sample saw the CCSSM as requiring teachers to teach both more conceptually and more procedurally. Three-quarters of the surveyed MSMTs stated that the CCSSM had caused them to change their classroom instruction. More importantly, MSMTs perceived that the CCSSM required them to provide more opportunities for students to struggle when solving problems.

The fifth factor, Teachers' Use and Reading of District-Adopted Digital/Electronic Resources, consisted of eight survey items and explained 4.6% of the sample variance. This factor includes the digital/electronic resources associated with the district-adopted curriculum. In addition, it also includes elements associated with the district-adopted curriculum such as its support for concepts and procedural fluency as well as the fact that this curriculum was adopted to support implementation of the CCSSM.

Table 5 shows similarities to MSMTs' use of digital/electronic resources from digital resources not associated with their district-adopted curriculum (Table 2). That is, MSMTs were more likely to use digital teacher resources than student text pages associated with their curriculum and

Table 4
Influence of the CCSSM on Classroom Instruction vis-à-vis Previous State Standards

Survey Item	Percentage Agree or Strongly Agree
The CCSSM have required you to change your classroom instruction.	75.0%
The CCSSM have required you to emphasize mathematical concepts more with your students.	77.8%
The CCSSM have required you to emphasize mathematical procedures more with your students.	64.3%
The CCSSM have required you to incorporate more student exploration.	73.7%
The CCSSM have required you to emphasize more mathematical communication.	85.9%
The CCSSM have required you to emphasize more solving of complex problems.	89.0%
The CCSSM have required you to provide more opportunities for students to struggle while solving problems.	79.7%
The CCSSM required you to change how you use curriculum materials.	77.0%

Table 5
Teachers' Use and Reading of District-Adopted Digital/Electronic Resources

Item	Moderately or Extensively
Read digital/electronic student text pages or worksheets	54.3%
Read digital/electronic teacher resources	73.2%
Use digital/electronic resources to plan primary activities for your lessons	69.0%
Use digital/electronic resources to create supplemental activities for practice or remediation	74.5%
Use digital/electronic resources to create inquiry-based activities	55.8%
	Agree or Strongly Agree
Your district adopted a new curriculum program to address the CCSSM.	65.5%
The district-adopted curriculum materials that you currently use support your students' development of computational or procedural fluency.	56.6%
The district-adopted curriculum materials that you currently use support your students' development of conceptual understanding.	61.5%

less likely to use digital resources to create inquiry-based activities. The majority of MSMTs sampled worked in districts that had adopted a new curriculum to address the CCSSM. The majority of MSMTs perceived that their district-adopted curriculum materials promoted procedural fluency as well as conceptual understanding.

The sixth factor, Strength of Perceptions of the CCSSM-based Assessments, explained 4.4% of the variance in the data and consisted of four survey items. MSMTs' perceptions of the CCSSM-aligned assessments appeared as a factor separate from their perceptions of the influence of the same assessments on various aspects of classroom instruction. As seen in Table 6, the majority of MSMTs sampled agreed that the CCSSM-aligned assessments will measure content appearing in the standards, but were less optimistic that these assessments will measure the SMPs or contain more complex problems. Nonetheless, MSMTs did feel that these externally produced assessments will measure content similar to their own classroom assessments.

The seventh factor, Extent of MSMTs' Planning Practices, explained 3.7% of the variance in the data and consisted of six survey items. This category included items such as the use of the CCSSM or other documents when planning and MSMTs' planning with colleagues or discussion of mathematics content when planning with colleagues. Despite the importance of planning in teachers' work (Clark & Peterson, 1986; Stigler & Hiebert, 1999), it was surprising that this factor was near the bottom of the list of factors associated with MSMTs' perceptions of the CCSSM and its impact on their instructional environment.

Table 7 displays the descriptives associated with the seventh factor. Two-thirds of respondents referred to the CCSSM document when planning lessons with fewer MSMTs using other documents to make sense of the CCSSM. District curriculum frameworks also play an important role in teachers' planning practices. Although studying student work can help teachers to plan in ways that promote student understanding especially when used within professional learning communities (Fulton & Britton, 2011), the majority of MSMTs did not engage in this activity on a regular basis when planning.

The last factor titled, Level of Perceived Rigor within the CCSSM, encompassed three survey items, explaining 3.4% of the variance in the sample. Two questions asked MSMTs about the CCSSM content and practice standards and rigor. The last question involved new content of the CCSSM. Thus, not only are teachers identifying new content for their grade level in the CCSSM they are also associating this the new content appearing in the CCSSM as rigorous when compared to their previous state standards. Despite the connection of rigor with new content, this factor was less important when compared with others such as the use of digital/electronic curriculum materials, explaining the least amount of variability in MSMTs' perceptions.

Table 6
Strength of Perceptions of the CCSSM-Based Assessments

Item	Percentage Agree or Strongly Agree
State assessments will be aligned with the CCSSM Content standards.	78.1%
State assessments will contain problems involving larger numbers, more decimals, and more fractions.	56.0%
State assessments will assess each of the eight CCSSM SMPs.	59.4%
State assessments will measure content similar to your classroom assessments.	64.2%

Table 7
Extent of MSMTs' Planning Practices

Item	Percentage Once or Twice a Week/Almost Every Day
Regularly study student work when planning.	42.5%
You refer to the CCSSM when planning.	66.6%
You refer to your district curriculum framework when planning.	62.0%
You refer to other documents that explain the CCSSM.	52.9%
	Agree or Strongly Agree
You regularly discuss mathematics content with colleagues.	74.4%
You regularly plan with colleagues.	64.9%

As seen in Table 8, a strong majority of MSMTs stated that both the content and SMPs were more rigorous than similar components of their previous state standards. In addition, a majority of MSMTs noted that the CCSSM contains new content for the grade level at which they teach.

Discussion

MSMTs' Use of Curricular Resources

Unlike previous research involving teachers' perceptions involving the CCSSM we explored a number of components at the intersection between curricular resources and the Common Core. Most of the teachers in our sample felt well prepared to teach the CCSSM yet around 40% of the teachers in our sample did not perceive their curriculum resources to align with components of the CCSSM. Indeed, the majority of our survey respondents noted that the CCSSM had caused them to change how they use their curriculum materials. These findings suggest fertile areas of research highlighted by the following questions: (a) How are teachers using their curricular resources differently due to the presence of the CCSSM? (b) What aspects of the CCSSM, their curricular resources, and the instructional environment have led to different curricular uses? Our study suggests that answers to questions such as these can help illuminate the nature of CCSSM implementation in middle school classrooms.

Moreover, our research suggests that teachers are frequently accessing both district-adopted and non-district-adopted digital resources as part of their planning for classroom instruction. Our results also indicate that these resources are used more often for remediation. Given the vast amount of mathematics education resources that exist online it is important to understand how teachers make decisions regarding these materials and how those resources connect to CCSSM-aligned instruction. Additionally, the factor analysis shows that MSMTs' use of digital resources associated with their curriculum is separate from their use of digital resources that they locate elsewhere; however, the latter factor was more important accounting for 9% of survey variation. The factor analysis also illustrates that non-district-adopted digital resources were not connected to the district-adopted print curriculum. This suggests a lack of curricular coherence, which may have negative effects on students' understanding of the mathematics represented in the CCSSM, especially as progressions within and across grade levels are an important component of these standards (McCallum, 2012). In sum, the proliferation of easily located, externally produced digital/electronic resources that teachers are using to supplement their district-adopted curriculum is an area in which future research needs to be conducted.

MSMTs' Perceptions of CCSSM-Aligned Assessments

Survey respondents reported less confidence in state-based CCSSM assessments in a number of different areas including assessing the CCSSM SMPs or their similarity to the MSMTs' own assessments. This conflicts with previous research (Choppin et al., 2013) and may reflect a shift in teachers' perceptions with regard to these assessments. One effect of this loss in confidence with regard to these assessments is their decreased influence on our survey respondents' classroom practices in terms of the content

Table 8
Level of Perceived Rigor Within the CCSSM

Survey Item	Percentage Agree or Strongly Agree
The Content Standards are more rigorous than your previous state standards.	85.5%
The Practice Standards are more rigorous than your previous state standards.	87.8%
The CCSSM represent new content for the grade level you teach.	82.5%

and practices they will emphasize on a daily basis. Many components such as communication and exploration are found in the SMPs. If MSMTs feel that the SMPs will not be assessed, they may be less likely to incorporate them in their daily practices. Research is needed to ascertain teachers' confidence that these assessments will align with all of the CCSSM (including the SMPs), how these perceptions will influence their classroom instruction, and how these changes will influence student understanding of content and the SMPs.

MSMTs' Perceptions of CCSSM Professional Development

Professional support explained the greatest percentage of variability among survey responses. The findings from the factor analysis suggest that professional development is linked with a number of important components of the CCSSM. For instance, professional development was associated with familiarity with the content standards and the SMPs, overall preparedness associated with the CCSSM, encouragement of new instructional approaches, and collaboration with teachers in other districts. This finding also illustrates the power of CCSSM professional development. That is, CCSSM professional development is associated with a number of different components that can assist with the implementation of these standards. Nonetheless, one-third of our respondents agreed that they had received inadequate professional development with regard to the CCSSM. This finding is similar to what previous surveys have found (e.g., EWRC, 2013). Despite experience implementing the CCSSM and receiving professional development with regard to it, teachers are still in need of professional development. Indeed, this matches what we know about professional development; it must continue over time (Clarke, 1994; Elmore, 2002; Hawley & Valli, 1999).

Our study also found that while teachers are very familiar with the CCSSM content standards for the grade levels that they teach, they are less familiar with the content standards for grade levels other than their own. This suggests one area in which teachers could receive CCSSM-based professional development. Given that one of the pillars of the CCSSM is coherence both from a mathematical logical perspective as well as a cognitive development perspective (McCallum, 2012), professional development focusing on content standards in other grades could also promote the progressions across grade levels in different content strands such as number and operations. The factor analysis suggests that promoting teacher collaborations across school buildings or districts is linked with preparedness and familiarity to teach the CCSSM. Thus, promoting these types of focused collaborations may be a viable form of CCSSM professional development.

Instructional Changes Due to the CCSSM

The results of our study indicate that MSMTs perceive that their instruction has changed due to the CCSSM. With regard to how that classroom instruction changed, survey results indicate that teachers are emphasizing both conceptual understanding as well as computational/procedural fluency. Given the historical emphasis on procedures in U.S. mathematics education classrooms (e.g., Stigler & Hiebert, 1999) this is indeed a hopeful sign that classroom instruction in the United States may be moving closer to the vision of mathematics education held by professional organizations (NCTM, 2014). Given the connection between student struggle and student achievement (e.g., Hiebert & Grouws, 2007), it is encouraging to see that the teachers in our sample perceived that the CCSSM provides more opportunities for students to struggle when attempting to solve problems in mathematics. Further, the factor analysis highlights that a number of changes associated with processes such as communication and exploration (NCTM) were connected with changes to classroom instruction as well as changes to how MSMTs use their curriculum materials. The finding that this factor explained the greatest variation in survey responses speaks to the potentially transformative role of the CCSSM. Nonetheless, these results suggest the need for further research to examine how these purported changes are reflected in the enacted curriculum. That is, teachers may simply be reporting on the survey what they think researchers want to hear.

Conclusions

This study moves beyond previous studies by focusing on MSMTs' perceptions of the CCSSM and its influence on components of the instructional environment such as curriculum resources in both print and digital forms. On the one hand, the results suggest that teachers may be using digital resources in ways that do not align with their district-adopted resources. On the other hand, the CCSSM appears to be influencing MSMTs' classroom instruction in more reform-oriented ways. The results of this study also suggest several fertile areas of research such as locating the factors that influence MSMTs' use of online digital resources and understanding the specifics regarding how the CCSSM changes teachers' enacted curricula. These are critical areas we need to understand in order to discern the impact of CCSSM at the middle grades.

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Appendix

Summary of Factor Analysis (N = 1,241)

	Rotated Factor Loadings							
Survey Item	1	2	3	4	5	6	7	8
Familiar with practices	**.80**	−.07	.03	−.04	.09	−.03	−.05	.08
Familiar with content standards	**.79**	−.08	.00	.04	.10	.00	−.08	.14
Familiar with content other grades	**.76**	−.06	.11	.10	.07	−.10	−.01	.03
Well prepared to teach CCSSM	**.76**	.01	−.06	−.03	−.09	.02	.01	−.02
Adequate professional development	**.55**	.10	−.02	−.01	−.16	.02	.20	−.05
Collaboration with other districts	**.51**	−.01	.04	−.07	−.05	−.01	.09	−.08
New instructional approaches	**.49**	.07	−.04	−.17	−.08	.06	.16	.01
Use DN* resources to plan	.06	**−.84**	−.08	−.06	−.11	.08	.07	.00
Use DN resources for remediation	.10	**−.82**	−.12	−.09	−.10	.08	.03	−.03
Use DN resources for inquiry	.09	**−.78**	−.10	−.09	−.16	.04	.07	−.05
Read DN teacher resources	.03	**−.75**	−.04	−.10	−.18	.03	.07	−.03
Read student-based DN resources	−.02	**−.68**	−.01	−.01	−.27	−.05	.08	−.01
Teacher evaluation influences instruction	.04	.11	**.72**	−.09	−.08	.00	−.06	−.06
Teacher evaluation influence classroom assessment	.08	.12	**.71**	−.05	−.08	.01	−.08	−.01
State assessments influence classroom assessment	.01	.00	**.67**	−.06	.00	.09	.00	−.07
Emphasis of assess on evaluation	−.02	−.01	**.52**	.05	.01	.17	.00	.04
State assess determine content/practices	−.03	.02	**.51**	−.01	.07	.27	.09	.01
Emphasize more communication	.13	−.07	−.02	**−.83**	.05	.03	−.10	−.12
Emphasize more exploration	.11	−.06	.01	**−.77**	−.02	.02	−.02	−.12
Emphasize more concepts	.04	−.02	.02	**−.76**	−.02	−.02	−.03	.04
Emphasize complex problems	.04	.00	.01	**−.73**	−.03	−.01	−.06	.13
More opportunities for student struggle	.05	.04	.01	**−.68**	.02	.03	−.06	.08
Change classroom instruction	−.13	−.08	.06	**−.58**	.06	−.04	.10	.15
Emphasize math procedures	−.11	.04	.04	**−.58**	−.03	−.06	.05	.02
Change how you use curriculum	−.08	−.12	.08	**−.43**	.09	−.05	.13	.15
Read DA† teacher resources	−.03	−.18	.09	−.01	**−.77**	.03	−.08	−.01
Use DA to plan	.03	−.24	.08	.09	**−.77**	−.05	−.07	.08
Read DA versions of student text	−.11	−.16	.03	.02	**−.74**	−.05	.02	.02
Use DA for remediation	.05	−.24	.05	.08	**−.70**	−.07	−.02	.04
Use DA for inquiry	.09	−.27	.04	.00	**−.66**	−.06	−.03	.00
Curriculum supports concepts	.12	.41	−.11	−.11	**−.52**	.11	.20	−.05
New curriculum for the CCSSM	.05	.33	−.06	−.14	**−.48**	.06	.13	.06
Curriculum supports procedural fluency	.14	.40	−.10	−.15	**−.44**	.04	.19	−.07
State assessment aligned with class assess	.00	−.06	.11	.00	.00	**.72**	.04	−.02
State assess measure SMPs	−.07	−.06	.12	.05	.02	**.68**	.03	.10
State assess complex problems	−.03	−.01	.04	−.01	.04	**.67**	.03	−.03
State assess aligned with content	.01	−.04	.20	.08	−.03	**.67**	.03	.06
Plan with colleagues	.04	−.05	−.10	−.01	.06	.14	**.84**	−.03
Discuss content when planning	.12	−.06	−.11	−.05	.03	.18	**.79**	.00
Study student work when planning	.11	−.05	−.09	.01	−.03	.02	**.74**	−.04
Use district framework to plan	−.07	.05	.16	.01	−.07	−.19	**.41**	.03
Refer to other docs when planning	−.04	−.17	.28	.01	.03	−.33	**.37**	.11
Use the CCSSM when planning	.09	−.09	.31	.00	−.01	−.33	**.35**	.02
Rigor in CCSSM content standard	.03	.09	−.07	−.12	−.07	.01	−.04	**.84**
CCSSM represent new content	.06	.02	−.05	.06	.00	.08	.05	**.79**
CCSSM SMPs are more rigorous	.07	.05	−.03	−.13	−.07	.01	−.09	**.79**
Eigenvalues	4.50	4.25	3.08	4.97	4.79	2.49	3.56	2.69
% of variance	16.1	9.3	7.1	6.3	4.6	4.4	3.7	3.4
α	.81	.92	.70	.84	.83	.73	.70	.79

*This refers to digital resources that do not accompany the district-adopted textbook.

†These include digital resources that accompany the district-adopted textbook.

Note. Factor loadings of at least .4 appear in bold.

How Picture Books on the National Science Teacher's Association Recommend List Portray Scientists

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This study utilized the Draw-A-Scientist Test Checklist (DAST-C) to assess the illustrations of scientists in the most recent three years of NSTA Recommends book lists. A total of 15,778 images were contained in the 148 books from those lists, of which 1,676 were of scientists. ANOVA procedures revealed no significant differences in stereotypical elements across the three years of books. However, three notable stereotypical elements were present in large percentages in books from all years: predominance of male images, non-minority scientists, and scientists who were not youthful.

Literature is often a bridge into the sometimes difficult and intimidating world of teaching science because some elementary teachers are more comfortable with language arts than science (Kazempour, 2014). The use of trade books and picture books to integrate literacy into science instruction time is commonly used as a means of maximizing students' understanding of specific content-related concepts. One of those concepts encompasses what scientists look like, who they are, and what they do—what is called "perceptions of scientists." However, there is concern that some books containing illustrations of scientists can actually create or increase misconceptions about scientists. Helping teachers make good choices about what picture books they introduce to their students may impact students' understanding about where scientists work and what they do. It may also influence some children in terms of interest and engagement in career choices (Archer et al., 2010; Shope, 2006). Those choices can be influenced by students' perceptions about scientists. The perceptions of scientists students hold may relate to their attitudes toward science and scientists (Finson, 2003; Fung, 2002). O'Brien, Kopala, and Martinez-Pons (1999) linked self-efficacy to the probability of an individual choosing a career in that field. It also has implications regarding the formation of science identity in children, as noted in the work reported by Farland-Smith (2012). Science identity includes one's perception that he/she can be a successful investigator in science contexts and is viewed by others as being competent in science (Brickhouse & Potter, 2001; Carlone, 1994; Farland-Smith, 2012). From the above, one could reasonably conclude that individuals who hold negative perceptions of science or scientists may be unlikely to pursue science courses or select science as a career. One way to address these issues is through the use of science trade books and picture books in instruction (Farland, 2006a,b; Farland-Smith, 2012).

Embedded within perceptions of scientists concerns are issues concerning the portrayal of scientists in terms of what they do and how they do it. In brief, how science is represented as a human endeavor has been consistently addressed in early science education reform documents and through more recent science reform efforts. Science as a human endeavor is a significant component of both the AAAS (1993) Benchmarks for Scientific Literacy (Project 2061) and the National Science Education Standards (NRC, 1996). The NSES delineated how science as a human endeavor was evidenced by three factors: (1) people are engaged in science and technology for a long time, (2) those who have contributed throughout history to the knowledge base have been both men and women and of various ethnicities–some of whom make careers in the sciences, and (3) science is an ongoing endeavor that does not end. This advocacy about the human side of science has continued in the most recent NRC (2012) standards—A Framework for K–12 Science Education. The Next Generation Science Standards (NGSS Lead States, 2013) explain the importance of K–12 students coming to know how scientists have investigated and answered fundamental questions in addressing major challenges facing society. The standards delve in depth about this human face of science through Dimension 1 (Scientific and Engineering Practices). It would seem logical that science educators would, therefore, look for ways to help students see science as a human endeavor. There are, of course, multiple ways this can be addressed. One of them is through the use of trade books and picture books that children can relate to and enjoy reading (Segun, 1988; Tapscott, 2009). While both text and illustrations function

together to promote comprehension (Hibbing & Rankin-Erickson, 2003; Martinez & Harmon, 2012; Verhallen & Bus, 2011), pictures can also help readers relate to characters when the illustrations are reflective of the readers themselves (Hefflin & Barksdale-Ladd, 2001; Roethler, 1998). Furthermore, books that contain stereotypical illustrations can be problematic (Mendoza & Reese, 2001), but those in which students can see themselves, or relate to, are viewed as positive and motivational (Al-Hazza, 2010). Additionally, there is some evidence that young children can visualize themselves in a science-related role via pictures in a children's book (Pantoya, Aguirre-Munoz, & Hunt, 2015). Therefore, illustrations of scientists can be important when engaging students in visualizing science as a human endeavor.

The purpose of this study was to investigate the illustrations, images, or photographs of scientists portrayed in picture books promoted for use in elementary and middle school classrooms. The focus was not on the stories being told in the books, but on what the scientists looked like and what they were doing. The books examined in the study were those that have been promoted by the National Science Teachers Association through its *NSTA Recommends* book lists. By their inclusion in these lists, books are implicitly viewed as being well vetted and of high quality with regard to their use in classrooms.

Theoretical Framework

Typically, an individual will become more likely to engage in science and view themselves as someone who does science (e.g., a scientist) if he/she can match his/her perceptions of what a scientist is like to his/her perception of self. This is particularly true for children and adolescents and is referred to as self-to-prototype matching theory (Rawson & McCool, 2014). The self-to-prototype matching also has implications with regard to one's science identity, which is essentially how one views self as being able to participate successfully in science and how one is viewed by others as being successful in science (Archer et al., 2010; Farland-Smith, 2012). By the time children reach adolescence, they have well-developed perceptions of what scientists are and their own science identities, and those perceptions usually run counter to what science educators desire them to be. This has long-term consequences with regard to adolescents' choices of taking additional coursework in science, pursuing science-related hobbies, and later choosing careers in science and science-related fields (Hannover & Kessels, 2004).

There are a number of potential sources of influence that impact learners' development with respect to their science identities and perceptions of scientists. Such sources could include role models, parental influences, school influences, and media (Farland-Smith, Finson, Boone, & Yale, 2014; Steinke et al., 2007). Of these, media were found to have some of the most significant impacts on children's science identities. Media consist of multiple things, including television, movies, the Internet, and books. A common medium utilized by parents and teachers is trade books. Trade books, by definition, are books published for the general public and usually convey information in a story-type format, unlike textbooks that present factual or descriptive information and are usually not available to the public at large. Trade books, particularly picture books, are often the first exposure children have to what scientists are like (Rawson & McCool, 2014). If constructed well, trade books can provide students with images of scientists and what scientists do—to which the students can relate and constructively build their self-to-prototype schema. Poorly constructed trade books may very likely convey stereotypical images of scientists that fail to help learners develop positive self-to-prototype perceptions and positive science identities. An example would be having minority students and/or females read a trade book showing a middle-aged male Caucasian scientist—a representation that those students cannot easily relate to. Good, Woodzicka, and Wingfield (2010) noted that such disconnects can adversely impact students' academic performance. Unfortunately, the predominance of Caucasian males in trade book illustrations has continued (Delgato, 2009; Elgar, 2004; Kahveci, 2010; King & Domin, 2007), and balance in representations of gender and minority figures remains unattained (Rawson & McCool, 2014). This state of affairs has considerable implications for science education and the populating of science careers in the future.

From the foregoing, it is reasonable to conclude that the teacher's selection of trade books for use in the classroom becomes an important consideration with regard to students' formation of science identities and self-to-prototype conceptualization. To help in this endeavor, some organizations such as the National Science Teachers Association have undertaken the task of vetting science trade books and generating lists of them to recommend to teachers for their use. The obvious assumption is that if such organizations have vetted the trade books, then teachers should not be concerned about the way those books portray scientists or the work they do. However, this assumption may be erroneous and is worthy of closer examination.

Background

Sources of Children's Perceptions of Scientists

Exactly where children derive their perceptions of scientists has been a question not easily resolved. In their 2014 study, Farland-Smith et al. identified a variety of potential sources of influence that could contribute to children's perceptions of scientists. Among those influences were media (such as movies, television, and internet); books (including picture books, comic books, etc.); parents (e.g., imparting of values, informal activities); and schools (e.g., activities that occur there). The researchers had 206 elementary students sketch multiple pictures of scientists, and then conducted interviews with the children to ascertain what the students were drawing from when creating their illustrations. Media sources were found to contribute to students' perceptions of scientists, although each of the sources had some degree of influence.

In 2006, Farland reported that some third-graders' perceptions of scientists were affected through weekly readings of nonfiction, historical-based trade books that depicted the work of scientists. Bazler and Simonis (1990) noted the messages delivered through textbooks showing scientists were clearly that science was a male endeavor and accomplishments of females were missing, trivialized, or even criticized. When females were included in the books, they were presented as having passive roles. Further, the books contained a dearth of topics that would be of interest to females.

Importance of Images

Quality illustrations in picture books include colorful images students will want to look at and be able to refer to over and again (Verhallen & Bus, 2011; Xiung, 2009). Analysis of images usually differentiates between photographs and other types of illustrations, and considers their attributes, qualities, and appropriateness for use with targeted student age groups. Children have particular preferences for images that help them comprehend the content being presented in books (Fang, 1996; Glenberg & Langston, 1992), and this becomes important to consider when books are being selected to help teach concepts, even if those concepts are indirectly taught, such as when attributes of scientists are included but are not the primary construct intended to be conveyed by the illustrations.

Included in the extant research regarding the impact of illustrations and photographic images on elementary children were examinations of attributes such as color (bold and bright versus muted and pastels), realistic versus conventionalized presentation, sharp versus rounded lines, line drawings versus drawn images, and drawings/paintings versus photographs. Rationales for considering the importance of such elements encompass improvement of reader comprehension and development of specific language. The overall design of visual features and illustrations typically guide the reader in comprehending and linking elements of stories (Andrews, Scharff, & Moses, 2002; Wolfenbarger & Sipe, 2007). Appropriate and well-done illustrations help children develop a language of science (beyond simple vocabulary), extending to the language of inquiry: observation, logically derived hypothesizing, question-posing, and examination of evidence (Pappas, 2006). Gains in these understandings of the language of science can be helpful to children as they develop their perceptions of what scientists do and how they conduct science investigations.

Additionally, how children see themselves in picture book illustrations is important to developing an interest in reading. Hefflin and Barksdale-Ladd (2001) interviewed African American adult and children readers, who expressed desires to see themselves in what they were reading. It was only when the books included characters with whom they could relate that readers began to feel connected to books and developed more interest in reading. Conversely, characters presented in books can also be viewed by nonminority readers as conveying clear messages regarding who can fulfill the roles characterized in books. As an example, children's book author Myers (2014) recounted an interview involving two equally qualified applicants for a chemist's job. Myers's colleague had to be convinced to send the African American applicant to the lab for an interview because the colleague could not believe the minority applicant was actually a chemist, despite his résumé. Myers alluded to the idea that the colleague's perceptions about who could be a chemist were derived, in part, from what the colleague had read in children's books while growing up, and those books simply did not show real scientists being from minority populations. Myers's conclusion was that children's books have a powerful role in promoting such roles for both minority and majority people, and that these notions carry forward into adulthood.

Content Analysis

The books that were analyzed in this study were the books in the National Science Teachers Association's *NSTA Recommends* book lists for 2014, 2015, and 2016. Children's picture books are books that not only tell a story, but give the reader an experience that is visual in nature, and is a book that "displays respect for children's understandings, abilities and appreciations" (ALSC, 2016). Children's chapter books are those that rely on the written text to convey a story or information. Trade books are defined by Durkin (1974) as books written for use in

Table 1
Number of Books on NSTA Recommends List

2014			2015			2016		
# on NSTA List	# Assessed	% Assessed	# on NSTA List	# Assessed	% Assessed	# on NSTA List	# Assessed	% Assessed
55	16	29.09	49	22	44.89	44	18	40.90

libraries or bookstores rather than being utilized as textbooks. Need a sentence or two here about how NSTA selects the books for NSTA Recommends (Donna?) The specific targeted group of books from the *NSTA Recommends* lists were picture trade books that contained illustrations of scientists.

The specific number of books on the *NSTA Recommends* list varied across the three targeted years, as shown in Table 1. As with the number of images in the books across the three years, the actual number of images of scientists also varied (see Table 2), ranging from a low of 4.18% in the 2016 books to a high of 18.34% in 2015. From these data, no particular trend in the number of images of scientists included in books could be identified. Some of the books showed scientists that could clearly be categorized as working in earth, life, or physical science. A total of 57 of the books could be classified as having orientation toward one of these three disciplines. The majority of images that could be classified in this way were of life and biological sciences (nearly three times the other disciplines), followed next by earth and then by physical science (see Table 3).

Instrumentation

The instrument utilized in this study was the Draw-A-Scientist-Test Checklist (DAST-C). The DAST-C was constructed using elements identified from a number of past studies on perceptions of scientists going as far back as the 1950s, beginning with the classic Mead and Metraux study in 1957, and then followed by Chambers (1983). Mead and Metraux (1957) asked 35,000 high school students to write essays in which they described what they thought scientists looked like. The perception that emerged from the essays was that scientists were elderly or middle-aged males wearing white lab coats and eyeglasses, working in dangerous laboratory settings. Chambers (1983) built from that work to develop the DAST, differing from the work done by Mead and Metraux in that students were not asked to write anything but were asked to make drawings. His analysis of drawings brought to light that seven specific attributes existed that were persistent across drawings. Those attributes were men wearing lab coats and eyeglasses, having facial hair (like beards or mustaches), surrounded by symbols of research (e.g., scientific instruments), symbols of knowledge (e.g., books, periodic tables, filing cabinets), technology (e.g., rockets, computers), and relevant captions (e.g., "eureka!" or formulae). These attributes have become recognized as the elements comprising the "stereotypical" scientist.

In their 1995 study, Finson, Beaver, and Cramond built upon Chambers's work to develop a checklist-type instrument that could help quantify the attributes arising in drawings done by children about scientists. They called their instrument the DAST-C. The DAST-C incorporated the attributes (or characteristics of scientists) identified by the foregoing researchers, and placed those elements in the upper portion of the checklist. These elements included the presence of lab coats, eyeglasses or other eyewear, facial hair, symbols of research, symbols of knowledge, and technology. Then they expanded the checklist items to include other attributes that seemed to frequently appear in drawings and, to some extent, reflected other things Chambers had noted in his work. Those additional checklist items included such as the ethnicity, gender, and age of the scientist, as well as the scientist's environment (doing work indoors, for example, or in areas of secrecy and/or danger). The additional elements also included mythic stereotypes

Table 2
Number of Images in NSTA Recommends Books

2014			2015			2016		
# of Images	# of Scientist Images	% of Images that are Scientists	# of Images	# of Scientist Images	% of Images that are Scientists	# of Images	# of Images of Scientists	% of Images that are Scientists
6,591	677	10.27	4,361	800	18.34	4,764	199	4.18

Table 3
Scientists' Disciplines in Book Images

Year	Discipline			
	Earth	Biology	Life	Physical
2014	2	1	7	3
2015	6	4	11	3
2016	4	2	11	3
Total	12	7	29	9

(e.g., wild-haired and buzzing-eyed mad scientist-typologies or Frankenstein characteristics) and the presence of ideas represented by flashing light bulbs. These additional elements were included in the lower portion of the DAST-C. In a way, the lower portion of the DAST-C can help illuminate the human endeavor aspect of what the scientist is doing since it helps one derive information about the environment in which the scientist is working and something about what the scientist is doing.

When using the DAST-C, the presence of any of the elements is scored with a "1" (even if there are multiple appearances of that same element in the image), and the total is then added to derive a score for the drawing. Scores can be determined for the upper portion of the DAST-C (the classic portion), for the lower portion, and for the overall total. Essentially, the higher the total DAST-C values, the more stereotypical the image is (although this does not necessarily or always translate into negative stereotypes, as might occur when one should see a scientist wearing a lab coat when working with chemicals).

The DAST-C developers reported the instrument had a high inter-rater reliability (0.97–0.98) as determined using ANOVA procedures (Finson, Beaver, & Cramond, 1995). They also established instrument validity by conducting face-to-face structured interviews with subjects regarding their perceptions of scientists, and then compared interview results to those obtained just using the DAST-C. The developers' conclusion was that the interview data closely matched DAST-C results, thus providing clear validity for the instrument. The instrument was later validated via other studies examining diverse populations such as racial groups (Finson, 2003), writing proficiencies (Monhardt, 2003), and national and cultural origin (Narayan, Park, Peker, & Suh, 2013; Turkman, 2008) including studies conducted in not only the United States, but also in China, India, South Korea, Taiwan, Turkey, and the UK.

Methodology

The initial pool of picture books included for consideration in the study were those recommended by the National Science Teachers Association in its *NSTA Recommends* book lists for the years 2014, 2015, and 2016. In total, 148 books were identified for examination. Not all books on the *NSTA Recommends* lists were considered picture books because the lists included chapter books for grades such as high school, and the focus of this study was on books for primary and middle school levels. (Note: Picture books are generally used in grades 3–5 and lower.) All 148 books were obtained through library sources. Since the researchers wanted to assess the appearance of scientists in the books, only those books that included images of scientists were selected for further examination. A total of 56 books (37.83% of the 148 books) included images of scientists. In that subset of books, a total of 15,778 images were available for assessment, but only 1,676 (10.66% of the images) were actually of scientists. To be counted as a "scientist illustration," the illustration had to either be showing a person traditionally perceived as a scientist or a person doing science of some sort.

Once the pool of books to be studied was established, the number of illustrations within each book were counted. In total, 15,778 pictures were available for analysis. The books with the highest number of illustrations were ones that were a type of resource or glossary like a DK Publishing book and typically had many small pictures arranged in a collage-type of style on the pages. Any of the books containing at least one picture of a scientist was considered as available for analysis.

Considering the large volume of pictures now available for analysis, a protocol was implemented to allow for easier management of picture assessment. For books having five or fewer scientist pictures, all pictures were analyzed. For books having more than five scientist pictures, five pictures were randomly selected from the book for analysis with the assumption that those five would not vary significantly in their characteristics from the other pictures in the book. The decision to randomly select scientist images for assessment from books containing many images was based upon sampling protocols often used in research studies. In our initial review of the books assessed in the study, we found the books having many images of scientists typically repeated images having the same scientist attributes without adding notable other attributes that would add to the measure of stereotypical elements. Our consensus was that assessing a specified number of randomly selected images from those books would yield the same whole-book DAST-C value as would be determined if all images in the book were included in the assessment.

As an example, in the book *Primates* by Ottaviani and Wicks (2013), there were 495 pictures of scientists.

Table 4
Presence of DAST-C Elements in NSTA Recommends Books

Element	2014		2015		2016	
	f	% of Time DAST-C Element Appears in Year of Books	f	% of Time DAST-C Element Appears in Year of Books	f	% of Time DAST-C Element Appears in Year of Books
Lab Coat	0	0.00	10	9.43	6	8.11
Eyeglasses	17	19.54	18	16.98	8	10.81
Facial Hair	18	20.69	20	18.87	19	25.68
Symbols of Research	2	2.30	0	0.00	0	0.00
Symbols of Knowledge	0	0.00	0	0.00	0	0.00
Technology	0	0.00	0	0.00	0	0.00
Male Gender	56	64.37	78	73.58	53	71.62
Caucasian	83	95.40	103	97.17	66	89.19
Indications of Danger	0	0.00	0	0.00	0	0.00
Presence of Light Bulbs	0	0.00	0	0.00	0	0.00
Mythic Stereotypes	1	1.15	0	0.00	0	0.00
Indications of Secrecy	0	0.00	0	0.00	0	0.00
Scientist Doing Work Indoors	6	6.90	22	20.75	7	9.46
Middle-Aged or Elderly Scientist	37	42.53	34	32.08	9	12.16
Total n =	87		106		74	

However, the entire book was about the work of Jane Goodall, Dian Fossey, and Biruté Galdikas, and the pictures essentially repeated the same set of characteristics throughout the book. Another protocol applied in the study for management purposes was to establish inter-rater reliability among the researchers on their assessments of the books. A random sample of 31 pictures was taken from the three years of books and scored independently by each of the three researchers using the instrument (DAST-C) chosen for analysis. Each researcher scored all 31 pictures, and those scores were then compared to determine inter-rater reliability, which was found via ANOVA procedures to be $r = .84$. Once this was established, the group was confident that images scored by any one of the researchers would be scored nearly the same as if scored by others in the research group.

Table 5
Basic Statistics for DAST-C on Stereotypical Elements in NSTA Recommends Books

	2014*	2015*	2016*
Upper DAST-C Mean	0.87	0.76	1.01
Upper Range	0–1.80	0–1.67	0–3.00
Upper *SD*	0.582	0.621	0.751
Lower DAST-C Mean	2.21	2.23	1.89
Lower Range	1.0–3.6	1.2–3.4	1.0–3.0
Lower *SD*	0.778	0.611	0.476
Total DAST-C Mean	2.56	2.55	2.37
Total Range	0–4.8	0–4.4	0–4.00
Total *SD*	1.32	0.972	0.951

*n of Scientist Images: 2014 = 677; 2015 = 800; 2016 = 199.

The DAST-C was then applied to each of the selected pictures. DAST-C scores were calculated for each picture. The scores of all the pictures in a single book were then used to calculate a mean DAST-C value for the book. This procedure also enabled the researchers to determine a DAST-C mean for all books within a given year of the *NSTA Recommends* lists.

Analysis and Results

The DAST-C was applied to each of the scientist images from the *NSTA Recommends* books. The data from this application are shown in Table 4, and some basic statistics are presented in Table 5. No statistical differences were found via ANOVA procedures for any element between the years. One interpretation of such a result is that the kinds of images included in the books selected by NSTA for its *NSTA Recommends* list remained relatively constant across the years. However, there are three particular elements in the DAST-C results (all from the lower portion of the instrument) that warrant further thought. The three focus on gender, race/ethnicity, and age.

Conclusions/Discussion

Stereotypical versus Nonstereotypical Portrayals

Research about the presence and influence of stereotypical images of science and scientists is plentiful, and most often reveals stereotypical images are seemingly ever-present and very resistant to change (Finson, 2002). As a group, the illustrations of scientists in the *NSTA Recommends* lists would not be considered as being very

stereotypical based upon scores derived using the DAST-C. The data in Table 4 show that the means for each year (2014, 2015, and 2016) were below 3.0, which is a relatively low DAST-C score. This is a desirable result given science educators' attention to reducing students' stereotypical perceptions of scientists over the past 25 years. Hence, one might conclude that the books in the NSTA lists were clearly overcoming the resistance to change noted in 2002 by Finson. Even so, the percentage of time facial hair and scientists doing their work indoors remained high compared to most other elements in the DAST-C. Conversely, it seems odd having an absence or near-absence of DAST-C elements on technology, symbols of knowledge, and symbols of research. Seeing an absence of elements alluding to symbols of danger or secrecy and of mythic stereotypes is a positive result. Such results might be attributed to the book illustrations showing scientists more often in outdoor settings where such stereotypical elements are less likely to exist. Given these points, there are three that bring one to pause. Stereotypical elements of gender, race/ethnicity, and age were clearly present in the books across all three years.

Gender Issues

The images of scientists portrayed in the *NSTA Recommends* books are predominantly male. Just over 64% of the images in 2014 were of males, and that percentage increased for 2015 and 2016 (both exceeding 70% of the images). Some might construe facial hair as a way to "double count" maleness, or as representative of style but in the case of the DAST-C the idea of facial hair as being stereotypical originally referred to the "mad" scientist type of image children were producing in their drawings. These results seem to run counter to efforts of science educators to be more inclusive with respect to gender representation. As far back as 1989, Fort and Varney noted that even though 60% of the 1,600 students in their study were female, only about 10% of the drawings they obtained were of female scientists. Hence, little seems to have changed from that time up until 2016 with respect to female images of scientists in the collective consciousness. Notably, it is historically prevalent that females are very underrepresented in science fields and in science publications, and numerous efforts have been made to increase the role of females in science, beginning at the elementary school level and continuing post-college. One of the critical interventions for this has been providing role models and images of role models that are female. Where and when those interventions have been implemented, notable successes have been reported in changing students' perceptions about who can be a scientist (Finson, Beaver, & Cramond, 1995). In 2012, Farland-Smith examined the critical aspects for science identity construction in young girls dependent upon personal and social interactions between the girls and scientists. Bohrmann and Akerson (2001) similarly found that interventions including giving specific praise, utilizing guest speakers, viewing videos of scientists from minority populations, and ensuring equal participation in science activities by students of both genders resulted in students having fewer stereotypical images of scientists.

Textbooks, trade books, and media have clearly been identified as significant influences on students' formative perceptions about who scientists are and who can be a scientist (Farland-Smith, Finson, Boone, & Yale, 2014; Steinke et al., 2007). Picture trade books should include images of both males and females inasmuch it is historically appropriate. In addition, the images of persons included within a trade or picture book should be as non-stereotypical as possible (Farland, 2006a, 2006b). In their study, Farland-Smith et al. (2014) investigated the role of books (among other influences) in students' formation of perceptions of scientists. They found that females in their study sample exhibited a higher level of sophistication in their perceptions of scientists—i.e., more expansive—as compared to the perceptions of male students. They also found that books and media both appear to be greater influences on males than females, whereas school is a greater influence on females than on males. This is an important point because trade and picture books children read contribute to their perceptions of scientists and their science identities.

Race and Ethnicity Issues

Perhaps more concerning is what one finds when looking at the race/ethnicity data from the *NSTA Recommends* books. Caucasian scientists by far outnumbered any other races/ethnicities in each of the years of books. In 2014, fully 95.4% of the images were of Caucasian scientists. In 2015, it increased to 97.17%, and then slightly declined in 2016 to 89.19%. As for gender issues, science in the United States has largely been perceived as an enterprise for Caucasians. Students from underrepresented populations have difficulty seeing themselves in the role of scientist, and are critically in need of images and role models that might support their perception that scientists can be from all races/ethnicities.

Race and ethnicity have been issues with respect to perceptions of scientists for a very long time. In his 1983 study, Chambers found that Caucasian students typically drew images of scientists who were also Caucasian, but minority students rarely drew images of minority scientists, and instead typically drew images of Caucasian scientists.

Sumrall (1995) found similar results. In her study comparing U.S. and Chinese student drawings, Farland-Smith (2009) found that a number of stereotypical misconceptions students possessed depended significantly upon the culture in which children learn. This was echoed earlier by Cavanaugh and Cavanaugh (2005) in their work, in which they concluded that for many children, what is presented to them is often interpreted in ways that help them define what they perceive to be culturally acceptable thinking and behavior (Cavanaugh & Cavanaugh) and have some effect of children's idea of the word "scientist." Clearly, if minority students cannot self-identify and connect with the illustrations of scientists in picture books, then there is a decreasing likelihood those students will develop positive science identities, take further science, or eventually seek science careers.

Age Issues

Finally, with respect to the age of scientists, the images in the books seem to be getting younger. In 2014, 42.53% of the images showed middle-aged or older scientists, declining to 32.08% in 2015 and dropping to 12.16% in 2016. The stereotypical and historic image of scientist has been of men of middle age and older. To many young learners, such perceptual images deliver the message that science is not for younger people. As with gender and race/ethnicity issues, serious interventions have been undertaken to dispel this perception. The trend in the *NSTA Recommends* books from 2014 through 2016 show a very positive move in presenting scientists as increasingly younger people with whom students can more easily relate and—as a consequence—see themselves emulating in the future.

Implications

It is important that teachers plan student-centered activities that give them the opportunity to explore their world and encourage them to think of themselves as scientists. By explicitly selecting books reinforcing nonstereotypical characteristics of scientists, teachers can plan and deliver instruction that enables students to progress toward that goal and successfully address key components of state and national reading and science standards. It is similarly important that agencies such as NSTA take additional steps to ensure the books in their recommended reading lists reinforce nonstereotypical images of scientists inasmuch as possible, and go the additional step of including and promoting images that are more inclusive in terms of gender and race/ethnicity.

It is likely many teachers rely on the guidance from respected book listings such as *NSTA Recommends* to select trade and picture books to use in their classrooms in their efforts to convey to their students the idea that science is something accessible, and is a "human endeavor." With regard to teachers and science educators choosing or recommending books from lists such as *NSTA Recommends*, it may be warranted they give additional attention to the way scientists are portrayed in the books rather than automatically accepting the books as appropriate due to their inclusion on the list.

The results of this study indicate that science educators, teachers, professional organizations and publishers all need to be clearly aware of what constitutes stereotypical representations of scientists and work to minimize such representations in the materials they use with students. Employing such diligence will positively contribute to the ongoing efforts from the past 25 years to present science as a more inclusive discipline that is open to females and minorities. Such action will move science education forward, help ensure that national standards are met, and bring strengthening diversity to the field.

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A Districtwide Study of Automaticity When Included in Concept-Based Elementary School Mathematics Instruction

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While conceptual understanding of properties, operations, and the base-ten number system is certainly associated with the ability to access math facts fluently, the role of math fact memorization to promote conceptual understanding remains contested. In order to gain insight into this question, this study looks at the results when one of three elementary schools in a school district implements mandatory automaticity drills for 10 minutes each day while the remaining two elementary schools, with the same curriculum and very similar demographics, do not. This study looks at (a) the impact that schoolwide implementation of automaticity drills has on schoolwide computational math skills as measured by the ITBS and (b) the relationship between automaticity and conceptual understanding as measured by statewide standardized testing. The results suggest that while there may be an association between automaticity and higher performance on standardized tests, caution should be taken before assuming there are benefits to promoting automaticity drills. These results are consistent with those that support a process-driven approach to automaticity based on familiarity with properties and strategies associated with the base-ten number system; they are not consistent with those that support an answer-driven approach to automaticity based on memorization of answers.

Introduction

The value of students being able to access math facts in a timely manner is well established (Caron, 2007; Woodward, 2006); however, approaches differ on how this should be attained. The National Council of Teachers of Mathematics (NCTM, 2014) suggests that the Common Core State Standards in Mathematics (CCSS-M) are designed so students can obtain access to math facts through procedural fluency obtained by an "understanding of properties, operations, and the base-ten number system" (CCSSI, 2010; NCTM, p. 73). This perspective would encourage students not to memorize a math fact such as $8 + 7 = 15$ but rather to revisit strategies such as $8 + 7 = 8 + (2 + 5) = (8 + 2) + 5 = 10 + 5 = 15$ until the associated properties and operations become second nature to the student and the math fact is retrieved in a timely manner.

Others believe that memorization of math facts is a viable approach to success in mathematics. Renaissance Learning, a company that has marketed materials, including *MathFacts in a Flash*, a system that includes computer-based math fact drills that could be used for memorizing math facts, asserts that:

> Declarative memory (which recalls that things are so) not only speeds up the basic arithmetic operations themselves (Garnett & Fleischner, 1983), it also acts to "free up working memory capacity that then becomes available to address more difficult mathematical tasks" (Pegg, Graham, & Bellert, 2005, p. 50). (2015, p. 5).

This study focuses on a school district where both the NCTM and the Renaissance Learning perspectives for math fact acquisition were present. The three elementary schools in the district are blue ribbon schools and administrators within the district have long valued the acquisition of math reasoning skills and selected *Everyday Mathematics* (The University of Chicago School Mathematics Project, 2007) as the district math curriculum in order to focus on math problem-solving skills over rote memorization of procedures (Fuson, Carrol, & Drueck, 2000). Teachers at these three elementary schools attended the same district-based professional learning to assure fidelity with the curriculum and commonly engaged in practices to encourage sense-making including number talks, use of manipulatives, and individual/small group mathematics projects to explore mathematics connections and concepts.

Table 1
Percent of Students Attaining Automaticity by School and Grade following the Automaticity Initiative at School 3 in the 2012–2013 Academic Year

Grade	School 1	School 2	School 3
Third	23.88	20.69	80.00
Fourth	66.22	45.65	82.76
Fifth	60.00	71.26	83.33

Over the past 15 years, it was quite common for this district to observe average percentile rankings in the math applications sections of the Iowa Test of Basic Skills (ITBS) that were over 20% points higher than the average percentile ranking in the section on math computation. In response to this long-standing result, automaticity resources that could potentially encourage memorization were made available to elementary schools in the district with the expectation that this would improve results on the mathematics computation section of the ITBS.

While all three elementary schools in the district had access to automaticity materials, only one school (School 3 in Table 1) mandated 10 extra minutes per day of automaticity drills using math fact retrieval tools consistent with recommendations of the Institute for Educational Sciences (delineated in the following section). This was in addition to the normal classroom instruction using *Everyday Mathematics*. The other two elementary schools continued concept-based instruction using *Everyday Mathematics* in their classroom instruction but, while they certainly provided "normal" encouragement for students to learn their math facts, did not mandate that classroom time be devoted to automaticity drills. While most automaticity activities consisted of individual students performing basic drills on a computer, teachers indicated that oral games, timed tests, songs, and mnemonic devices were also used. Table 1 presents the automaticity rates achieved in the study's three schools by the completion of the 2012–2013 school year as measured by the automaticity test described in Table 2.

Automaticity rates at School 3 were over 80% for the third, fourth and fifth grades. As this was the only school to systemically incorporate automaticity drills into their curriculum, it is not surprising that their automaticity rates were the highest in the district, particularly in the third grade.

These results provided an opportunity to study the impact of automaticity in two populations with similar demographics that used the same curriculum; one where automaticity drills were mandated and automaticity was achieved quickly, and the other where automaticity drills were not mandated and automaticity appeared to develop more slowly. Specifically, this study will examine individual and schoolwide data associated with these two within-district populations to ascertain the impact of mandated schoolwide automaticity. At the school level, we

Table 2
Measures Used in the Study

Assessment	Description
Automaticity Tests	Automaticity with multiplication facts was determined by administering a three-minute test of 60 single-digit multiplication items. A copy of a sample multiplication fact test is included in Appendix. Each student was given three minutes to complete as many problems as possible. They were graded to determine how many items were answered correctly in three minutes. If a student answered less than 55 items correctly in three minutes, the student was considered not automatic. If a student was able to answer 55 items correctly in three minutes, the student was considered automatic. If all 60 questions were answered correctly in three minutes, the student was considered perfectly automatic.
Iowa Test of Basic Skills (ITBS—Mathematics Computation Section	This section of the Iowa Test of Basic Skills indicates that (ITBS, 2015): "each problem requires one arithmetic operation - addition, subtraction, multiplication, or division. The problems require operations with whole numbers, fractions, decimals, and various combinations of these, depending on the test level."
Kentucky Performance Rating for Educational Progress (KPREP)	The most common assessment associated with understanding of mathematics concepts in Kentucky is the mathematics section of the KPREP which is described by the Kentucky Department of Education (KDE, 2015) as "a blended model built with norm-referenced test (NRT) and criterion-referenced test (CRT) items which consist of multiple-choice, extended-response and short answer items. The NRT is a purchased test with national norms and the CRT portion is customized for Kentucky." Students are classified as novice, apprentice, proficient or distinguished based on the KPREP exam. In Kentucky performance reviews, scores of proficient and distinguished are considered consistent with an understanding of mathematics concepts appropriate for the students' grade level. When describing students, the term proficient refers to students that are proficient or distinguished. The term not proficient refers to students that are classified as novice or apprentice.

will look at the impact of automaticity drills on schoolwide performance on the computation section of the ITBS. At the student level, we will explore the broader relationship between automaticity and conceptual understanding of mathematics when a statewide standardized test is used to assess students' conceptual understanding.[1] Finally, we discuss some of the potential considerations associated with these results.

Background

Schoenfeld (2004) described mathematical competence as having both the knowledge of facts and "the ability to solve problems in new contexts or to solve problems that are different from the ones one has been trained to solve" (p. 262). How to help students in gaining this mathematical competence has been subject to many debates on what should be taught and how. Some of the catch-phrases associated with this debate include Math Wars, Back to Basics, and New Math. To be successful, students need procedural fluency that is "the ability to execute action sequences to solve problems" and a conceptual understanding, which can be considered "implicit or explicit understanding of the principles that govern a domain and of the interrelations between units of knowledge" (Rittle-Johnson, Siegler, & Alibali, 2001, pp. 346–347). Rittle-Johnson et al. (2001) in their study of fifth- and sixth-grade students found that procedural and conceptual knowledge can operate in concert among successful students. Many aspects of these discussions are mirrored in studies of how students should best learn basic arithmetic facts.

The definition of automaticity as the "single-step retrieval of solutions from memory rather than some algorithmic computation" (Logan & Klapp, 1991, p. 179) is often associated with almost instantaneous retrieval of math facts. However, based on research by Isaacs and Carroll (1999), The *MathFacts in a Flash* materials used by the schools in this study recommended three seconds per problem for students in elementary school. This automaticity goal was adopted by the school district in this study and is important because it allows enough time per problem for students to use non-memory-based approaches when accessing math facts.

The Everyday Mathematics curriculum, used by all three schools in this study, moves "from nearly exclusive emphasis on naked number calculation to developing conceptual understanding and problem-solving skills in arithmetic" (Everyday Mathematics, 2017a). Keeping with this goal, lessons in the Everyday Mathematics curriculum associated with multiplication facts use patterns and structure to access math facts (Everyday Mathematics, 2017b). While Everyday Mathematics certainly promotes conceptual approaches to accessing multiplication facts, it also suggests the use of "written and choral fact drills" (Everyday Mathematics, 2017c) to help students develop ready access math facts. Hence, multiplication fact drills are not necessarily inconsistent with Everyday Mathematics. However, as Everyday Mathematics is quite specific on what methods should be used to access math facts and as these specific methods do not include memorization, we would consider memorization of math facts to be inconsistent with this curriculum.

Proponents of memorizing math facts often refer to the practice of overlearning which can be thought of as practicing that which has already been learned over and over again until it becomes second nature (Renaissance Learning, 2015). While overlearning can be used with conceptual strategies for obtaining math facts, proponents of memorizing math facts assert that a one-step, faster is better approach has benefits that multi-step cognitive strategies do not provide. With ready access to basic math facts, students are less likely to be overwhelmed by the amount of cognitive engagement problems often require and will be better positioned to solve more complex problems (Sweller, 1994). Several other studies (Ashcraft, 1992; Campbell, 1987; Compton & Logan, 1991) assert that remembering memorized math facts quickly will free cognitive capacity and result in greater success with more complex problems.

On the other hand, some studies discourage a memorization approach to math facts. Clark and Kamii (1996) found that multiplicative thinking appeared early and developed slowly in children and discouraged a "faster is better" mentality toward math facts. An evaluation of student performance on the 2012 Programme for International Student Assessment (PISA) found that the lowest performing students were those who used a memorization strategy (Boaler, 2015) and that success achieved through fact mastery is likely not achieved through memorization alone. More importantly, Marshall (2003) found that once facts are learned using rote memorization, it can be difficult to attempt to teach for understanding retroactively.

Reviewing available research, a panel from the Institute of Educational Sciences (IES) (2009) for the "What Works Clearinghouse" acknowledges both answer-driven automaticity based on memorization and process-driven automaticity based on strategies and properties. They indicated it was important to attend to

conceptual underpinnings rather than "solely relying on rote memorization and drill and practice" (p. 43); noting that students should be able to use the distributive property to convert a more complex product into two simpler products. However, the panel also recommends spending "time after instruction with extensive practice on quick retrieval of facts through the use of materials such as flash cards or technology" (p. 43) for struggling students. The IES recommendation to extensively practice "quick retrieval of facts" with "materials such as flash cards or technology" was interpreted by the school district of this study as promoting "quick retrieval" with no restrictions on how to achieve it. In other words, while not necessarily to be encouraged, memorization of math facts was considered a viable approach to "quick retrieval." Also, while the IES recommends potentially considering 10 minutes of automaticity drills for students that are struggling with basic math facts, one of the schools of this study widened implementation of automaticity drills to include all students.

Research Questions

We pose two research questions to provide insight into the ongoing debate on both the benefits of mandated automaticity drills and the benefits of automaticity itself. As the school district of this study was primarily interested in improving computation skills as measured by standardized tests, our first research question addresses whether mandated schoolwide automaticity drills are an effective strategy to achieve this.

Research Question 1 (RQ1): What is the relationship between implementation of mandated automaticity drills for all students and schoolwide performance on mathematics computation standardized tests?

As the school district had a history of success with conceptual understanding of mathematics as measured by standardized tests, we felt that this context for an automaticity initiative might provide new insight into the broader relationship between automaticity and conceptual understanding of mathematics topics.

Research Question 2 (RQ2): What is the relationship between automaticity and conceptual understanding as measured by proficiency on statewide standardized tests?

An important distinction to make between these two research questions is that the first seeks conclusions associated with the schoolwide implementation of automaticity drills and hence schoolwide results are the focus. The second looks for general associations between automaticity and proficiency and does not consider which school a student attends.

Study Design

Study Participants and the Nature of the Automaticity Initiative

All students in the third, fourth, and fifth grades during the 2012–2013 academic year from the three elementary schools in this district participated in the study. Of these students, 217 were third-grade, 230 were fourth-grade, and 224 were fifth-grade students. Roughly 93% of students in the district were Caucasian, 50% were female, 14% received free lunch, and 3% received reduced lunch. Over 99% of students who graduated from the one district high school that year went on to college, and the district was ranked in the 98th percentile in the state. The study participants attended three elementary schools that feed into the same middle school and are all within three miles of each other in the same demographically homogenous community. All teachers were certified and highly qualified according to Kentucky standards with no difference in recruiting practices, pay, benefits, training, or development opportunities for teachers at these three schools. All three schools are also characterized by very low staff turnover.

In January 2013, the automaticity initiative described in the introduction was launched using the *MathFacts in a Flash* (which has now been renamed *Accelerated Math Fluency)* program with all third, fourth, and fifth grade students. A significant part of the initiative was computer drills. While all arithmetic facts were included in the overall initiative, multiplication math facts are the area of focus in this study. *MathFacts in a Flash* broke down multiplication facts into the following levels:

Multiplication by 0, 1	Multiplication Review: 0 to 5	Alternate Forms: Multiplication by 6 to 10
Multiplication by 2, 3	Multiplication by 6, 7	Multiplication Review: 6 to 10
Multiplication by 4, 5	Multiplication by 8, 9	Multiplication Review 1
Alternate Forms: Multiplication by 0 to 5	Multiplication by 10	Multiplication Review 2

Each level included the following:

1. Baseline Test: Students completed a timed test for each new math level.
2. Personalized Practice: Students practiced a variety of problems at their current level, including any problems missed on the previous test.
3. Timed Tests for Mastery: Students completed 60-item timed tests.
4. Automatic Advancement: Students moved to the next level after meeting their individualized goal on the test.

5. Instant Information for Teachers: Detailed reports gave teachers an instant snapshot of student progress.

While *MathFacts in a Flash* was available to all three schools, two of the schools continued providing the same conceptual instruction concerning multiplication facts and simply provided access for students to voluntarily supplement their normal activities with automaticity drills. Similarly, the third school continued to provide the same conceptual instruction but mandated that all of its students receive 10 additional minutes of direct math fact instruction daily. It also included math fact instruction as part of its school improvement plan and mandated that all students participate in an end of year math fact tournament. These initiatives were considered consistent with the IES recommendation of "10 minutes a day" and learning math facts "through the use of materials such as flash cards or technology" and *MathFacts in a Flash* had advertised its product as being "in line with the IES Practice Guide." It is, however, certainly worth noting that, in contrast to mandating automaticity drills for all students, the IES recommendations were limited to students struggling with mathematics.

The results in Table 1 indicate a significant difference between end-of-year automaticity rates achieved at School 3 where automaticity drills were mandated and Schools 1 and 2 where automaticity materials were available but voluntary. Hence, as mandated versus voluntary automaticity drills produced significant differences in automaticity rates in populations that were otherwise very similar, this study explores other differences and similarities among students in these populations. As it is difficult to monitor approaches that students may take to learning math facts, the two populations of this study, students in schools where automaticity drills were mandated and students in schools where automaticity drills were voluntary, reflects a common reality for many classrooms, schools, and districts.

Methodology

Timeline and description of assessments used in this study. Table 2 presents the assessment tools that were used in this study. Table 3 provides the timeline for administering these assessments and for administering the automaticity initiative.

Methodology addressing Research Question 1. In order to assess the impact of mandated automaticity drills on mathematical computation skills as measured by the ITBS, the following data were tabulated and analyzed:

- The average national percentage on the computation section of the ITBS for each grade and school on the ITBS assessment before the automaticity initiative (in October of 2012) and following the automaticity initiative (in October of 2013).
- Preintervention to postintervention growth was measured by calculating, for each school, the change in the average national percentage from 3rd-graders in 2012 to 4th-graders in 2013 and from 4th-graders in 2012 to 5th-graders in 2013. As students generally advance a grade from 2012 to 2013, this better captures growth among the same students as they advance.

Methodology addressing Research Question 2. The authors certainly do not claim that proficiency on the Kentucky Performance Rating for Educational progress (KPREP) standardized test is a definitive indication of conceptual understanding of mathematics. However, from the released sample of questions (KPREP, 2012), we believe that many of the questions, particularly extended response questions that require students to show their work and explain their thinking, or questions that require the coordination of multiple representations, likely require more than memorization (Stein & Smith, 1998). So we consider proficiency, as measured by KPREP, is likely indicative, at least, of conceptual understanding beyond memorization of facts and procedures. Hence, while KPREP may be an imperfect absolute measure of conceptual understanding, we accept that a proficient student likely understands math concepts better than a non-proficient student so KPREP is effective as a relative measure in our study. In order to gain insight into the relationship between automaticity and conceptual understanding of mathematics as indicated by proficient or

Table 3
Timeline for Assessment Administration

Date	Assessment
October 2012	Students took the preinitiative ITBS.
January 2013–May 2013	Students participated in the automaticity initiative.
May 2013	All students in all three schools took the final automaticity test that was used to assess automaticity levels in this study.
May 2013	Students took the statewide standardized test to assess conceptual understanding (KPREP).
October 2013	Students took the postinitiative ITBS.

Table 4
Average National Percentile by Year and Grade of Students on the ITBS-Computation Assessment

	School 1		School 2		School 3	
Grade	2012–2013	2013–2014	2012–2013	2013–2014	2012–2013	2013–2014
Third	66	71	66	62	57	53
Fourth	62	61	58	50	55	50
Fifth	77	73	62	71	59	56
Average	68.3	68.3	62	61	57	53

distinguished ratings on KPREP assessments, the KPREP and Automaticity Test results were used to perform the following descriptive statistics and analyses:

- A table of the number of students, by grade, by automaticity level (not automatic, automatic but not perfect, or perfectly automatic) and by proficiency level (proficient/distinguished on the KPREP exam or lower than proficient) was constructed and statistical analyses were performed for each grade to determine whether automaticity was independent of proficiency. If automaticity is independent of proficiency, being automatic would not be associated with being proficient.

Where an association between automaticity and proficiency was found, follow up analyses explored the nature of this relationship. In particular, we explored to what degree proficiency might be expected to follow when students are automatic and to what degree automaticity might be expected to follow when students are proficient. To gain insight, quantitatively, into the degree to which being automatic implies being proficient, we tabulated:

- The percent of automatic students that were proficient and
- The percent of non-proficient students that were not automatic.

Logically, automatic implies proficient (direct form) and not proficient implies not automatic (contrapositive form) are equivalent; however, they represent different populations in the data. A high percentage in both these tabulations support the conjecture that proficiency follows as a likely consequence of being automatic.

Similarly, to assess the degree to which being proficient implies that one is automatic, we tabulated:

- the percent of proficient students that are automatic (direct form) and
- the percent of non-automatic students that are not proficient (contrapositive form).

Once again, a high percentage in both these tabulations support the conjecture that being automatic follows as a likely consequence of being proficient.

Results

This section first presents results regarding the relationship between mandated automaticity drills and schoolwide performance on the computation section of the ITBS that are associated with Research Question 1. It then presents general results on the relationship between student automaticity and proficiency as measured by statewide testing that are associated with Research Question 2. As the first research question explores the impact of mandated schoolwide automaticity drills on schoolwide performance on the ITBS, only schoolwide results are presented in the first section. As the second research question explores general relationships between automaticity and proficiency, students from all schools are treated as a single population and no school-specific results are presented.

Mandated Automaticity Drills and Computation Skills

The motivation for our first research question was that the district in this study expected higher automaticity rates to improve performance on the Mathematics Computation section of the ITBS. Hence, we started by tabulating the average national percentiles on the ITBS-computation assessments before and after the automaticity initiative to address whether this expectation is justified (Table 4).

Looking at the average national percentiles for each grade and school on the ITBS-Computation Section, we can see from Table 4 that based on the preintervention (2012–2013) average over three grades, the ranking of the schools is: School 3 < School 2 < School 1. Based on the average postintervention (2013–2014) national percentages over three grades for each school, the ranking is also: School 3 < School 2 < School 1. Hence, the district and all of the principals felt that the best measure to assess performance would be to observe relative growth from preintervention to postintervention scores as the same students advance a grade.

Table 5 shows the growth in the average percentile on the computation section of the ITBS as students proceed from the administration of the ITBS immediately before the automaticity initiative in 2012–2013 to the administration

Table 5
Growth in Average National Percentile on the ITBS-Computation Assessment as the Same Students Advance a Single Grade from Prior to the Automaticity Initiative to Following the Automaticity Initiative

	School 1	School 2	School 3
Third grade to fourth grade	−5	−16	−7
Fourth grade to fifth grade	+11	+13	+1
Average	+3	−1.5	−3

of the ITBS following the automaticity initiative in 2013–2014 as the students advance a grade (see methodology for RQ2 in Section 4.2). On average, School 1 was the highest performing school of the three in terms of student growth. School 3 significantly outperformed School 2 in terms of student growth from the third to the fourth grade and School 2 significantly outperformed School 3 in terms of student growth from the fourth to the fifth grade. When considering the average of each school's two percentile growths (Table 5), the ranking of the schools is School 3 < School 2 < School 1.

Automaticity and Proficiency

Our second research question addresses the relationship between students' automaticity and conceptual understanding as determined by the KPREP assessment. Table 6 presents the number of students by grade, by proficiency status and by automaticity level during the 2012–2013 academic year.

For each grade, a Pearson chi-square test of independence was performed on the 3 by 2 subtable associated with the given grade. In grade 3, automaticity and proficiency are independent so there is no significant association between automaticity and proficiency. The proficiency rates is slightly higher among the automatic students; however, this difference is not statistically significant ($p > .25$). In fourth and fifth grades, however, automaticity and proficiency are not independent ($p < .01$) so there is a significant association between proficiency and automaticity.

Pursuing the nature of the association between automaticity and proficiency in the fourth and fifth grades, Table 7 presents the populations associated with the direct and contrapositive forms for the conjectures that (a) automaticity implies proficiency and (b) proficiency implies automaticity.

For both conjectures, more than 70% of the associated populations satisfy the direct form of the conjecture. However, in both cases, less than 60% of the associated population satisfy the contrapositive forms for the same conjectures where 50% would represent a total lack of evidence either for or counter to the conjecture.

Discussion

This study focuses on students from three demographically similar schools that were within a short distance of one another, where all students used the same mathematics curriculum dedicated to conceptual understanding of mathematics concepts. As one of these three schools mandated 10 minutes of automaticity drills each day for every student in the school and the other two schools had no mandated automaticity drills, this provided a rich population of students that, while similar in terms of demographics and curriculum, were potentially different in the manner by which they learned their math facts.

Research Question 1 addresses whether there is evidence that mandated schoolwide drills to promote rapidly achieving automaticity with multiplication facts improve computation skills as measured by the ITBS. While the three elementary schools in the district were very similar in most ways, School 3 was different from the other two schools in terms of (a) having mandated automaticity drills and (b) having significantly more automatic students (see Table 1). Correspondingly, an effective approach to RQ1, is to observe the results of the ITBS using students from School 3 as an experimental group and students from Schools 1 and 2 as the comparison group. However, as can be seen from Tables 4 and 5, School 3 is the lowest performing school based on both average scores and preintervention to postintervention growth. Hence, regarding RQ1, there was no evidence that mandated automaticity drills, even when accompanied by higher automaticity rates, positively impact scores on the computation section of the ITBS.

Table 6
Number of Students by Automaticity Levels, Proficiency Status, and Grade in the 2012–2013 Academic Year

	Grade 3		Grade 4		Grade 5	
	Not Proficient	Proficient	Not Proficient	Proficient	Not Proficient	Proficient
Not Automatic	46	86	41	42	27	33
Automatic (not perfect)	7	23	22	47	11	49
Perfectly Automatic	10	32	6	62	13	78

Table 7
Percentages Associated With the Association Between Proficiency and Automaticity

	Grade 4	Grade 5
The percent of the automatic that are proficient (direct)	80%	84%
The percent of the non-proficient that are not automatic (contrapositive)	59%	53%
The percent of the proficient that are automatic (direct)	72%	79%
The percent of the non-automatic that are not proficient (contrapositive)	49%	45%

Research Question 2 addresses the relationship between automaticity and proficiency as measured on the statewide standardized test, KPREP. Although the third grade curriculum is rich with content associated with multiplication facts, there were only moderate differences, far from statistically significant, in the proficiency rates among the non-automatic and automatic groups of students in the third grade. In the fourth and the fifth grades, however, the difference in the proficiency rates between automatic and non-automatic students was statistically significant ($p < .01$) (See Table 6). As automaticity is not associated with proficiency in the third grade but is associated in the fourth and fifth grades, this would indicate that potentially, the nature of automaticity may have been different among students in the third grade versus students in the fourth and fifth grade. In the third grade, about two thirds of the automatic students were from School 3 where automaticity drills were mandated while about one third were from Schools 1 and 2 where they were not. Hence the majority of automatic students in the third grade had spent 10 minutes per day on mandatory automaticity drills. In the fourth and fifth grades, however, the majority of automatic students were from schools 1 and 2 and had not been required to spend 10 minutes per day on automaticity drills. So it is possible that the lack of association in the third grade may be a result of a population of automatic students dominated by those that were required to perform automaticity drills. And the positive association in the fourth and fifth grades may be a result of a population of automatic students dominated by those that were not required to perform automaticity drills.

These results are consistent with the NCTM perspective that the CCSS-M is designed to develop procedural fluency based on conceptual understanding over time. This perspective might suggest that quickly achieved automaticity without explicit attention to understanding the underlying properties and operations, is not expected to impact or be associated with KPREP results which are presumably based on the CCSS-M. With respect to the second research question, a new finding of this study was a yearlong delay before an association was identified between multiplication math facts and proficiency in mathematics. This result would support Clark and Kamii's (1996) assertion that multiplicative thinking in children takes time and a "faster is better" approach to math facts may not be optimal.

There was an association between automaticity and proficiency in the fourth and fifth grade so, as part of RQ2, we explored the nature of this association. Table 7 shows that over 80% of fourth and fifth grade automatic students were proficient. However, Table 7 also shows that on average 56.5% of non-proficient fourth- and fifth-graders were not automatic. As there were a significant number of non-proficient students in grades four and five and as 50% would represent a completely neutral finding, we felt that the data for the contrapositive form of the conjecture were too weak to support the conjecture that automaticity implies proficiency. Similarly, Table 7 shows that about three fourths of fourth- and fifth-grade proficient students were automatic; but, less than half of non-automatic fourth- and fifth-graders were not proficient. Therefore, the data actually slightly contradict the conjecture that proficient implies automatic. As there were a significant number of non-automatic students in grades four and five and the data associated with the direct and contrapositive forms of the conjecture were contradictory, we did not feel there was evidence to support the conjecture that proficiency implies automaticity. So the data in this study supported neither proficiency as a consequence of automaticity nor automaticity as a consequence of proficiency among fourth- and fifth-graders. The most we could conclude in this study regarding the association between proficiency and automaticity among fourth- and fifth-graders was that there is a tendency for students in this district to share both of these characteristics after they have advanced beyond the third grade.

The results of this study can provide insight to teachers and administrators that are contemplating automaticity initiatives to improve mathematics standardized test scores. This study, as with others, did affirm an association between automaticity with multiplication facts and mathematics proficiency as measured by standardized tests. However, the results of this study would suggest that the

process by which automaticity is attained may be important.

As we discussed in the Introduction and Background sections of our article, proponents of a "faster is better" approach to retrieving of math facts often suggest that replacing a more extended cognitive process (figuring out a math fact through properties and operations) with a simple memorized result may free up cognitive capacity that can then be used to more effectively solve complex problems. We refer to such automaticity, achieved through memorization, as answer-driven automaticity. Counter to proponents of answer-driven automaticity, the work of Rohrer, Dedrick, and Burgess (2014) found that better long-term results were obtained when students revisit topics multiple times through diverse problems and contexts. Rather than overlearning answers for sets of very similar problems, this approach promotes procedural fluency through broad familiarity of associated strategies and properties. Hence, rather than focusing on quick retrieval of answers, this approach would focus on quick retrieval of properties and operations with the development of flexible thinking processes to apply them. We refer to automaticity borne of familiarity with strategies and properties as process-driven automaticity. We would consider process-driven automaticity to be consistent with the NCTM assertion that the CCSS-M is designed to achieve procedural fluency through familiarity with the properties and operations of the base-ten number system.

Our data indicate that automaticity that is more quickly obtained through automaticity drills does not appear to be associated with conceptual understanding as measured by standardized tests. Our data did indicate that automaticity obtained over a longer period of time, perhaps through familiarity with the properties and operations of numbers as the NCTM suggests should happen with the CCSS-M, is associated with conceptual understanding as measured by standardized tests. In the context of a broader discussion on process-driven automaticity versus answer-driven automaticity, our data would suggest that students would best benefit from the development of process-driven automaticity. Hence, when making decisions associated with automaticity interventions, administrators and teachers may wish to consider whether the intervention promotes process-driven or answer-driven automaticity.

Future Directions

This study has important implications for further research because it calls for more evidence to unfold the benefits and long term effects of process-driven automaticity approaches. While our study was quantitative in nature, we performed related observations of an automatic proficient student and an automatic non-proficient student that received conceptual classroom instruction from the same mathematics teacher; however, both experienced supplemental mandated automaticity drills. When asked to make up a number story to show the meaning of 2×6, the proficient automatic student spoke of two plates with six cookies on each plate. This would represent the highest level cognitive construct (Clark & Kamii, 1996), 2×6 represents two sixes. However, the automatic non-proficient student responded "I have six cards and my friend has six cards. What is that put together?" This is certainly correct, however, it still addresses multiplication as repeated addition which is a lower cognitive construct (Clark & Kamii, 1996). Particularly in cases where conceptual understanding is partnered with math fact drills, an intriguing future direction might be qualitative research on whether mandated automaticity drills may shift students from process-driven to answer-driven automaticity, potentially stunting their conceptual development.

This study provides insight into the impact (or lack thereof) of automaticity drills among students that are, in general, not struggling with mathematics. However, the characteristics of the participating schools should be taken into account when generalizing results. All three schools in the study were Blue Ribbon schools with above average student performance and all three schools were invested in building a strong mathematical foundation for students based on conceptual understanding. In future studies, it would be interesting to see whether these results would be replicated in a lower performing school district committed to conceptual understanding or in school districts with more procedural approaches to mathematics education. The recommendations provided by IES mainly targets struggling students, so it may be interesting to see how all the associations explored in this paper would look in such a setting.

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Authors' Note

[1]It should be noted that the authors do not necessarily endorse this standardized test as a single definitive measure of conceptual understanding; however, this was the available instrument designed for this purpose.

Appendix
Sample Multiplication Facts Automaticity Test

1	2	1	5	1	3	2	3	1	2
× 1	× 3	× 2	× 1	× 4	× 3	× 2	× 1	× 0	× 5
8	2	5	1	8	7	3	4	7	4
× 1	× 6	× 3	× 9	× 5	× 1	× 9	× 2	× 9	× 4
4	3	0	3	8	6	9	2	5	7
× 7	× 4	× 6	× 7	× 3	× 5	× 9	× 8	× 9	× 7
9	7	7	4	6	2	6	5	5	6
× 6	× 6	× 8	× 8	× 12	× 9	× 6	× 7	× 5	× 1
4	2	5	8	0	2	8	9	0	4
× 0	× 10	× 4	× 6	× 3	× 7	× 8	× 12	× 8	× 9
11	9	9	11	4	4	12	6	12	5
× 8	× 6	× 8	× 3	× 6	× 5	× 3	× 3	× 12	× 12

Examining the Types, Features, and Use of Instructional Materials in Afterschool Science

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Afterschool programs have garnered much attention as promising environments for learning where children can engage in rich science activities. Yet, little is known about the kinds of instructional materials used in typical, large-scale afterschool programs that implement science with diverse populations of children. In this study, we investigated the types, features, and use of science instructional materials at more than 150 public afterschool program sites across California. Using afterschool site survey data, we categorized the types and the range of materials used at the sites. We then collected a subsample of the instructional materials for in-depth analysis of their support features for enabling staff and children to enact science. We also interviewed afterschool site staff to better understand how they selected and used materials. Results from our analysis of survey and interview data show that afterschool staff primarily used stand-alone lessons and activities found on the Internet or in activity books as resources for planning and enacting science. Our analysis of the subsample of instructional materials indicate that curricular materials, while used less frequently by afterschool staff, have on average more of the support features that would help them implement high-quality science experiences with children.

AFTERSCHOOL programs are increasingly seen as important settings where ambitious science learning can occur. Within the past 15 years, funding for development and research on out-of-school programming for science has dramatically increased, resulting in the creation of new programs and instructional materials for afterschool science (e.g., Lawrence Hall of Science, 2009; Lyon, Jafri, & St. Louis, 2012) as well as a growing body of research literature (e.g., National Research Council [NRC], 2009). In the area of afterschool programming, research shows that afterschool settings can play a critical role in providing children with access to rich science learning opportunities by substantially expanding the time children have to explore science (Coalition for Science After School, 2007). These opportunities can be considered especially important for elementary-aged children, given the education policy context wherein science instruction in elementary schools is often undervalued and its presence is modest (Banilower et al., 2013; Marx & Harris, 2006).

Beyond simply extending the school day, or providing more school-like instruction after school, afterschool settings offer a unique learning environment often quite different from the traditional school structure (Eccles & Templeton, 2002). While afterschool programming has increasingly focused on academic enrichment, the activities are often infused with a youth development perspective that emphasizes active and collaborative learning, developing a sense of mastery, and meaningful participation (Mahoney, Larson, & Eccles, 2005). By blending science education and youth development perspectives, many programs have demonstrated positive effects, such as improved attitudes toward science and science-related fields and careers, increased science knowledge and skills, and a higher likelihood of graduating and pursuing a science-related career (Chi, Snow, Goldstein, Lee, & Chung, 2010).

In recent years, state educational agencies and funders have begun to invest in large-scale afterschool initiatives. As these initiatives are realized, it will be important to examine how they support science. At the present time, little is known about how to implement high-quality science offerings on a broad scale in typical afterschool programs that are not expressly designed as environments for science learning (Noam et al., 2010). There is, for instance, little research on the kinds of instructional materials used in typical, large-scale afterschool programs that provide services to diverse populations of children and implement science in their settings.[1] There is also a need for research on how the instructional materials that afterschool programs do use align with contemporary views on how learners can best be supported in out-of-school settings,

such as the principles for science learning described in the National Research Council's synthesis report on informal science learning (NRC, 2009).

In an effort to better understand the conditions under which science is provided in large-scale afterschool initiatives, we investigated the use of science instructional materials within and across sites of a statewide afterschool program in California. The publicly funded initiative provides support for community-based afterschool programming in all regions of the state. Our aim was to gain insight into the types of science instructional materials in use at the afterschool sites, the range of use of different types of materials, the kinds of support features provided within these materials, and how afterschool staff used the materials to plan and enact science.

Background

Afterschool Science

The field of afterschool science is growing and garnering increased attention as educators, researchers, and policymakers recognize that the hours after school can provide unique time and structure for engaging children in science. In response, an impressive array of stakeholders—foundations, government agencies, informal science institutions, universities, and national youth organizations—have made investments in providing afterschool opportunities in science. Many recently developed initiatives serve diverse youth populations and aim to increase the participation of low-income youth and underrepresented groups in science, notably minority youth and young women (e.g., Lyon & Jafri, 2010).

Contemporary views on how learners can best be supported in out-of-school settings have been highlighted in the National Research Council's (NRC) synthesis report, *Learning Science in Informal Environments* (NRC, 2009). The report illustrates how informal learning environments can play a distinct and substantive role in promoting meaningful engagement in science. Moreover, the report recommends that informal learning environments have clear learning goals, are highly interactive, include multiple pathways for children to engage with science, facilitate science learning across settings, promote engagement and learning over extended time, and draw upon children's interests, experiences, and prior knowledge to support rich learning (NRC, 2009). These recommendations reflect the emerging consensus on key principles that bring together views on science learning with youth development perspectives.

Although there is generally wide agreement about the tremendous potential for afterschool programs to accommodate powerful science learning experiences, there is evidence that these settings have their own challenges that can make it hard to enact science well. For instance, afterschool staff members responsible for enacting science with children often have neither a science background nor an understanding of how to orchestrate rich science activities (e.g., Noam, Dahlgren, Larson, & Dorph, 2008). Moreover, high turnover of staff is a persistent problem (Dennehy & Noam, 2005) that thwarts efforts to provide long-term professional development. Even when science-oriented professional development is offered, it tends to be limited in terms of time and material resources, and of variable quality (e.g., Noam et al., 2008).

Science Instructional Materials

The term instructional materials encompasses a wide range of resources that can be used by educators to plan for and enact learning experiences for students. In general, they are the concrete resources—activity descriptions, lesson plans, and curricular modules—that provide educators with activities and guidance to help students accomplish particular aims (Ball & Cohen, 1996). In science education, these materials can take many forms including commercially based activity books that provide collections of science experiments or activities, science project kits such as butterfly hatching kits or model rocket kits, media resources such as educational science videos, trade books such as children's science books, and stand-alone lesson plans and activities downloaded from the Internet. They also can take the form of curriculum materials that organize activities and lessons into a coherent sequence of experiences that support learning over an extended period of time, usually over days or weeks, but sometimes over months and even years. While instructional materials can vary widely in design and purpose, an essential characteristic is that they provide some level of pedagogical support to educators (Ball & Cohen, 1996).

An important part of science instruction is using materials purposefully to make science accessible for students (Harris & Rooks, 2010). Instructional materials have been widely acknowledged for their central role in supporting learning in school-based environments (Ball & Cohen 1996) and have had a role in out-of-school learning environments, too (Katz & McGinnis, 1999). Well-designed materials with embedded support features can help educators with creating particular kinds of learning experiences (Singer, Marx, Krajcik, & Clay-Chambers, 2000) and even provide opportunities for educators to learn themselves as they teach (Davis & Krajcik, 2005). Support features can take the form of steps to follow, rationales for suggested actions, prompts or questions for use during instruction, and descriptions of outcomes to expect. Carefully designed support features have clear advantages—

they can provide background information on science content, give guidance on arranging the learning environment, suggest strategies for interacting with students, and help educators anticipate student thinking. Of course, not all instructional materials are designed well. Some can be overly prescriptive, thereby diminishing the decision-making role of educators and the autonomy of students (Shulman, 1983). At the other end of the spectrum, underspecified materials can make it difficult for educators to envision how the learning experience should unfold (Kauffman, Moore Johnson, Kardos, Liu, & Peske, 2002).

Educators' use of instructional materials has been a focus of research in school settings, and much of this research highlights that educators must thoughtfully interact with materials to make instructional decisions that meet the needs of their students. Following lesson or activity plans step-by-step may not lead to a successful learning experience for students (Davis & Varma, 2008). Likewise, straying too far from the lesson or activity structure risks that students will benefit less from the materials or not entirely meet the learning goals of the activity. Thus, in order to enact instructional materials effectively, it is important for educators to make interpretations and modifications consistent with the purposes and structures of the materials and consistent with their youths' learning needs and interests. These types of decisions, along with deciding how and when to enact lessons, are part of the important planning process that all educators must go through (Ben-Peretz, 1990). To date, there has been little research conducted on the role of instructional materials in supporting ambitious afterschool science.

Study Context

The work reported here is part of a multi-year study designed to investigate the nature of afterschool science offerings in a statewide afterschool program system in California, including the sources of support for science programming and afterschool staff development at program sites. California's After School Education and Safety (ASES) program supports "locally driven" afterschool services at schools and in other community settings. Afterschool sites within the system are organized at the community level and run by partnerships between schools and afterschool providers, typically youth and community-based organizations. More than 4,000 afterschool sites are funded through the program and serve over 400,000 youth in grades K–9 each year. Each ASES site serves children from a partner public school; only schools with 50% or more of their students eligible for free or reduced-price lunch can participate in the program. Most sites (89%) are affiliated with elementary schools that serve students from Kindergarten through 5th or 6th grade. In the present study, we sought to better understand the types and range of science instructional materials in use at the afterschool sites serving elementary-aged children, the kinds of supports provided within these materials, and how afterschool staff used the materials to plan and enact science. Our research questions were:

1. What are the types and range of the science instructional materials used by staff and participants across sites of a publicly funded statewide afterschool program?
2. What are the support features of the science instructional materials used by staff and participants in the afterschool program?
3. How do staff members select and use science instructional materials to plan and enact science activities at their afterschool program sites?

Methods

To address our research questions, we designed and administered a survey to a sample of afterschool sites serving elementary-aged children within the statewide ASES program. The afterschool science survey asked site coordinators to report on their site's science offerings, including the science instructional materials used by staff and participants. Next, we categorized the range of instructional materials identified by sites in the survey data. We then selected and gathered a representative sample of instructional materials and conducted an analysis of support features. Finally, we conducted semi-structured interviews with a sample of afterschool site personnel on how they selected materials and how they used them to plan for afterschool science.

Administering the Afterschool Science Survey

The afterschool science survey contained questions on frequency of science offerings and typical activities, types of instructional materials used, supports for activities, partnerships with science providers, and contextual factors related to capacity to deliver science instruction, such as staff at the sites and their qualifications. It also included questions regarding how decisions are made about science programming at the site level, including the staff person(s) responsible for selecting materials, activities, and science topics, and what factors shape their decisions.

Sample. To select our survey sample, we collected a stratified random sample of urban and rural ASES sites, with sites across the two strata matched on school-wide demographics and achievement variables. A stratified random sample of 600 sites was drawn from the roughly 3,700 elementary sites that comprised 89% of all the

publicly funded afterschool sites in California's ASES program at the time of the administration of the survey.

Comparison of the survey sample to the total population of ASES elementary afterschool sites indicated that the two groups were equivalent in terms of proportion of students eligible for free or reduced-price lunch, average Academic Performance Index (API) scores, average parental education, proportion of their school's teachers who were credentialed, and proportion of students in their school identified as gifted/talented. It is important to note, however, that the ASES elementary school-age population itself differs from the population of California elementary schools in a number of ways. Because only schools with more than half of their students eligible for free or reduced-price lunch are eligible for ASES afterschool programming, ASES elementary sites tend to have more non-White students, lower API scores, and fewer students identified as gifted/talented compared to California elementary schools as a whole.

Procedure. The survey was sent to 600 ASES site coordinators (i.e., on-site program supervisors) at each selected afterschool site during the 2010–2011 school year. The survey was administered both online and on paper, with the majority of respondents completing the survey online. The survey was in the field for a total of 15 weeks; 426 site coordinators completed the survey (71% response rate) during this time period. After eliminating incomplete surveys and surveys with errors, the final sample was 415 surveys.

Categorizing the Types of Instructional Materials

On the survey, site coordinators were asked whether or not they had offered science at their program site during the school year. Coordinators who indicated that they offered science were asked to name up to three different science instructional materials that were in use at their sites and that were representative of the kind of science resources typically used by staff; to briefly describe them; and to identify the source and publisher. We used this survey data to identify and categorize the types of instructional materials used by afterschool program sites.

Selection. We filtered our set of survey responses to create a subsample of program sites that had listed science instructional materials. First, we filtered on whether and how often sites offered science. From our 415 survey responses, 380 afterschool sites reported offering science. Next, we filtered for whether the sites had offered science during the school year in which we administered the survey and 294 sites remained. Finally, we filtered for whether the remaining sites listed science materials, and found that 159 sites nominated at least one material used in their after school science programming. This sample represented more than half of the sites that offered science during the school year and provided a rich and varied dataset for analysis.

Categories. The materials identified from the survey responses were each sorted into one of three broad categories: (a) science curricular materials, (b) science enrichment materials, or (c) non-materials. Curricular materials were defined as science units or modules comprised of sequenced activities with specifications for enactment over multiple sessions. These materials included teacher/instructor guides and provided opportunities for science learning over an extended period of time. Enrichment materials encompassed a broad array of stand-alone lessons and activities designed for short-term use. Instructional materials that were sorted into the enrichment category included prepackaged science projects, stand-alone activities or science lesson plan activities drawn from websites or books, and science trade books or media that were used to support science learning. These materials were typically not based on a logical learning sequence over time (e.g., related topics over multiple sessions that build upon each other) even though some activities within the books and websites were organized by science topic. Non-materials were defined as responses that were not science instructional materials or instructional activity resources for enacting science with children. These responses typically were science topics such as "weather" or "insects" that did not include any accompanying information regarding the instructional materials, or were externally delivered science events and fieldtrips.

We further delineated material types within our two broad focal material categories. For Curricular materials, we sorted each into one of three subcategories: (a) Out-of-school curricula (C1), (b) School-based curricula (C2), and (c) Context-independent curricula (C3) where the material was developed for cross-setting use (i.e., either in-school or out-of-school contexts). Enrichment materials were sorted into one of five subcategories: (a) Science lesson or activity plans from websites (E1), (b) Science lesson or activity plans from books (E2), (c) Trade book or media (E3), (d) Prepackaged science project (E4), and (e) Site-developed material or activity (E5). Materials identified from the survey responses that did not have sufficient information to assign them to a materials category were designated as "not codable for material type."

Procedure. The 159 sites nominated a total of 275 science instructional materials. All the nominated materials were identified and collected as either a digital or physical copy. As a first step in the analysis, the nominated materials were independently coded into the eight categories listed above by two researchers, one who categorized the full set

of materials and another who categorized a randomly selected subset of the materials (20%, $n = 55$). Afterward, the two researchers met to compare their categorizations, check for reliability, and calibrate their decision rules. When both were uncertain about a categorization, a third researcher provided judgment to help clarify and make a decision. As part of this process, the research team modified and refined the categories and their parameters. We then conducted a second round in which the two researchers revisited category assignments and either confirmed or reassigned materials based on the refined category parameters. The inter-rater agreement was 87%. Differences were resolved through discussion and consensus to reach a final categorization for each material.

Coding the Support Features of the Materials

Selection of materials. We used the results from our categorization of the instructional materials as the basis for selecting a subsample of materials for further analysis. We purposefully selected a proportional number of materials from each of five subcategories—the three subcategories of curricular materials (out-of-school materials, school-based materials, and context-independent materials) and two subcategories of enrichment materials (lessons/activities from websites [E1] and lessons/activities from books [E2])—that were representative of the majority (73%) of the materials in the overall material sample. We also ensured that the types of materials selected for coding were representative of the overall pool of nominated materials. Of note is that other enrichment subcategories did not lend themselves to further sampling and coding (i.e., site-developed materials [E5] would not be generalizable and trade books [E3] and prepackaged kits [E4] did not occur frequently) and thus were dropped from subsequent analysis. In all, 37 instructional materials were selected for in-depth support feature coding.

Coding scheme. We designed a comprehensive coding scheme to identify and analyze the full range of support features provided within the instructional materials. This coding scheme was based on the strands from the *Learning Science in Informal Environments* report (NRC, 2009) and *Taking Science to School* (NRC, 2007), as discussed in more detail below. The scheme measures instructional support across four dimensions: (a) content and structure of the activities, (b) usability for facilitators and children, (c) engagement for children and relevance to their lives, and (d) promotion of scientific thinking, reasoning, and practice. For each dimension, we specified a set of indicators for identifying support features within science instructional materials. A total of 61 codes represented the indicators for these four dimensions (see Appendix).

Dimension 1, content and structure of the activities, examines the features that help facilitators to structure the science activities into a coherent "storyline" for children to move along a pathway for learning. Indicators for this dimension are 14 codes that focus on such features as science learning goals, sequence and pacing, and allocating time for doing science. Dimension 2, usability, addresses features in materials that support enactment and accessibility for facilitators and children. This dimension contains 23 codes that address facilitator features, such as preparation for instruction, guidelines for orchestrating activities, and educative supports for effective enactment, as well as support features for children, such as directions and materials (e.g., activity sheets, science notebook, directions/procedures, and posters), and specialized supports for children of diverse backgrounds and abilities to access the science.

For Dimension 3, engagement for children and relevance to their lives, we established indicators for identifying features that attempt to bridge science to children's everyday social and physical world. These 11 codes include features for facilitators to situate learning in a context, such as a driving question, dramatic scenario, real-world situation, or compelling problem/issue; help children use their prior knowledge and interests for learning, and provide opportunities and support for children to make choices. Dimension 4, promotion of scientific thinking, reasoning, and practice, encompasses supports and prompts for facilitators to help children to think and reason about their science experiences and to effectively reflect on their learning. The 13 codes for this dimension include supports for facilitators and children to engage in science practices and productive discourse that encourages collective scientific thinking via discussion and debate.

The dimensions were constructed from the National Research Council's research synthesis reports on learning science in school (NRC, 2007) and out-of-school settings (NRC, 2009). Indicators were vetted against a review of research literature to provide an argument for the selection and inclusion of specific indicators under each dimension. It is important to note that the purpose of this coding scheme was not to determine the quality of instructional materials, but to identify important features of materials that could support the enactment of science.

Procedure. We collected the full set of instructional materials that comprised our subsample for coding. We used a small subset of the materials for refining the coding scheme and training on its use. Two researchers were trained on using the coding scheme and went through multiple practice rounds of coding with this smaller set. Once sufficient agreement—above 70% on the majority of the codes

(Stemler, 2004)—was reached in the practice rounds, each researcher was randomly assigned approximately 60% of the materials in the main set, with 20% of the materials coded by both researchers for reliability checking. The researchers met to compare codes, reach consensus on any disagreements, and assign final codes for all indicators. When both researchers were uncertain about a piece of evidence for coding a support feature, a third researcher provided judgment to help clarify and reach agreement.

We examined the 37 instructional materials at the lesson or activity level and conducted double sampling of lessons/activities when a given material included more than one lesson in order to account for some amount of range within the material (such as a book of science experiments or a textbook). In total, we coded 67 lessons/activities: 17 website-based lessons/activities (E1), 32 book-based lessons/activities (E2), 8 out-of-school curriculum-based lessons/activities (C1), 8 in-school curriculum-based lessons/activities (C2), and 2 context-independent curriculum-based lessons/activities (C3).

Interviewing Afterschool Site Staff

Our final step to understanding the role of instructional materials in afterschool science was to examine how staff members selected materials and the materials' role in planning for science. We conducted interviews with staff from 13 afterschool sites to better understand how these materials were situated within the science offerings provided at afterschool sites.

Selection of sites. Our selection process began with a sample of 119 candidate sites whose survey responses indicated that they had two or more sources of support for science, offered science at least once a week, and used science instructional materials. We further narrowed down our list by identifying sites that provided the most frequent science offerings and collectively represented a wide range of materials. We then contacted 36 of the most promising sites, resulting in 13 sites with staff members who agreed to participate in interviews.

Interview protocol. We developed a semi-structured interview protocol that addressed such topics as staff and site capacity for offering science, the process of selecting instructional materials, and how sites used materials to plan and prepare for science. To learn about staff capacity, the protocol included questions about site coordinators' and facilitators' experiences and perspectives on leading science activities with children, backgrounds in science, and training for afterschool science. Questions about site capacity included frequency of science offerings, and the physical space, materials and other resources available for science. The protocol also prompted interviewees to describe a recent or upcoming science activity as an entryway to conversation about materials selection and the activity planning process. Questions during this phase of the interview probed for the kinds of instructional materials typically used, the reasons and criteria for selecting them, constraints influencing the material selection process, the ways in which the materials were used to plan, and how they were used to enact science with children.

Procedure. Interviews were conducted via phone with afterschool site coordinators or facilitators who had knowledge of the process of selecting materials and planning for science at their sites. The interviews, lasting 45–60 minutes, were audio-recorded and then transcribed.

We used an inductive approach to identify themes within and across and transcripts. Topic codes were assigned to statements made related to different topics in each set of interview data, then compared across interviews, and finally condensed into a summary format. Each topic summary included exemplars that were representative of the interview responses. This process was carried out by two researchers who independently assigned topic codes and then met to discuss, resolve differences, and construct the summaries.

Results

Types and Range of Science Instructional Materials

Although 159 sites nominated materials in their survey responses, 13 sites were dropped from subsequent analysis due to their nominations being "non-materials" (i.e., not instructional materials). After this filtering, our analysis focused on 249 instructional materials nominated by 146 afterschool sites. Of the 146 sites, 85 sites reported one material, 28 sites reported two materials, and 33 sites reported three or more materials. As shown in Table 1, a majority of these materials, 71.9%, were science enrichment materials and 28.1% of them were science curriculum materials. Of the 179 science enrichment materials reported, most were lessons/activities from either websites or books. Out-of-school and school-based curricula were nearly evenly divided and comprised most of the materials in the curriculum category.

Use of materials by sites. We examined the range of materials that afterschool sites reported using and found that 106 (73%) of the 146 sites reported using at least one type of enrichment material while 61 sites (42%) reported using at least one type of curricular material. Regarding curriculum materials, 30 sites (20.5%) used out-of-school (C1) materials, 28 sites (19.2%) used school-based materials (C2), and 6 sites (4.1%) used context-independent materials (C3). On the enrichment side, 47 sites (32.2%) used lessons/activities from websites (E1), 38 sites (26.0%) used lessons/activities from books (E2), and 29 sites

Table 1
Categorization of Instructional Materials (N = 249)

Category	Code	Material Type	Frequency	%
Curriculum	C1	Out-of-school curricula	32	12.9
	C2	School-based curricula	30	12.0
	C3	Context-independent curricula	8	3.2
Enrichment	E1	Lessons or activities from websites	62	24.9
	E2	Lessons or activities from books	50	20.1
	E3	Trade book or media	7	2.8
	E4	Prepackaged science projects and kits	21	8.4
	E5	Site-developed material or activity	36	14.5
	E	General enrichment (source unknown)	3	1.2

(20.0%) used their own site-developed materials (E5). The two other types of enrichment materials (E3 and E4) were used by a much smaller number of sites, 4.8% and 13.0%, respectively.

Across the 146 sites that reported on material use in the survey, 40 sites (27.4%) used only curriculum materials, while 85 sites (58.2%) used only enrichment materials. Just 21 sites (14.4%) used a combination of the two categories. In general, sites used only one category of material, even if they used multiple materials in their program, and this was typically multiple enrichment materials. There were 61 sites that reported using multiple materials at their site and about one third of these sites reported using both curricular and enrichment materials.

Support Features of the Instructional Materials

In our examination of the support features found in the instructional materials, we found that, on the whole, curricular materials had more support features than enrichment materials. Additionally, materials that had a relatively high number of support features from one dimension on the coding scheme usually had a relatively high number of support features in the other dimensions. In other words, most materials either had many of the support features of interest or very few support features. Of note is that there were some features that were rarely seen across the full spectrum of materials. Both curricular and enrichment materials, for instance, were found to have minimal support features addressing social-emotional learning goals (i.e., engagement, motivation, and attitude toward science); use of science notebooks or journals to record work; prompts to coordinate prior knowledge with new knowledge; supports or prompts to encourage reflection on learning; strategies for facilitators to encourage children to listen and build on each others' ideas; and opportunities for children themselves to design experiments or investigations.

We performed a principle components analysis (PCA) on the dataset to see if we could reduce the dimensionality of the data. The first two dimensions only captured 32% of the variance of the dataset. Although the scores across the dimensions are correlated, which specific features materials are coded for are not—which is why the variance captured in the PCA is relatively low.

We examined the main differences in support features across the categories and subcategories of instructional materials for each of the four dimensions of instructional support: (a) content and structure of the activities; (b) usability for facilitators and children; (c) engagement for children and relevance to their lives; and (d) promotion of scientific thinking, reasoning, and practice. The accompanying box and whisker plot for each of the four dimensions shows each of the subcategory's median scores (i.e., the number of support features in that dimension) as well as the first and third quartiles and any outliers.

Content and structure of the activities. Regarding the first dimension, content and structure of the activities, Figure 1 shows that lessons and activities in the two curriculum categories scored much higher on support features than the lessons and activities in the enrichment categories. This trend holds for all four of the dimensions, but it is especially pronounced for this dimension. Of particular note are the high scores among the school-based materials, which perhaps are to be expected on this

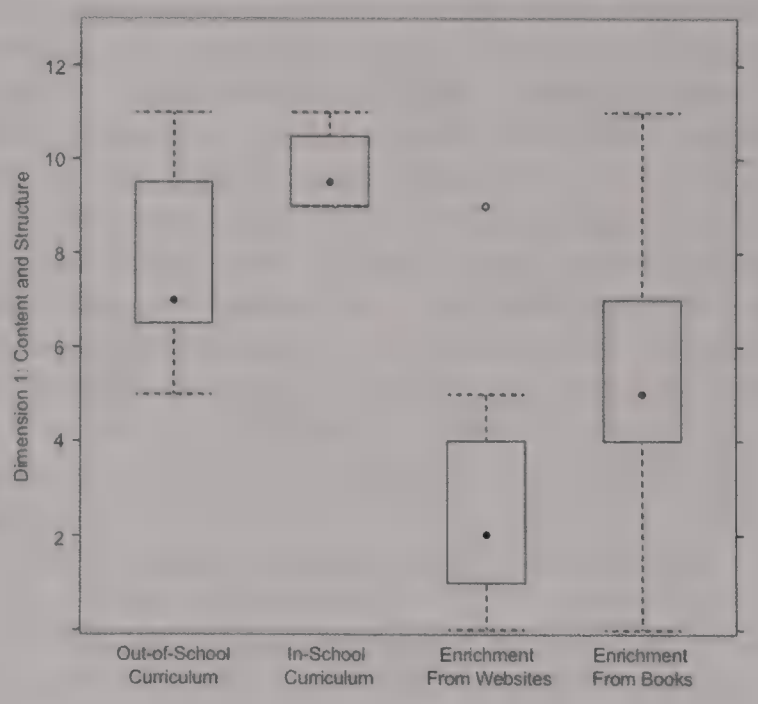

Figure 1. Box and Whisker plot for Dimension 1 (Content and Structure of the Activities) of the materials coding scheme, grouped by category.

dimension since it captures a focus on content and structure, which are hallmarks of materials for school settings. Among the lessons and activities from books (E2), Figure 1 shows a broad range on this dimension, highlighting the wide degree to which materials in this subcategory vary in terms of support features for content and activity structure. Overall, curriculum materials were more likely than enrichment materials to identify the age/grade-level appropriateness of the lessons or activities, specify an expected time frame for completing them, and provide a clear sequence to the lessons or activities. Also of note is that curriculum materials were more likely to include scientific practices among learning goals. Other support features in this dimension were either similarly present or absent across the two categories of materials.

Usability for facilitators and children. Regarding usability for facilitators and children, the second dimension, Figure 2 shows that the lessons and activities found in out-of-school and in-school curriculum materials scored much higher in support features than the lessons and activities from websites and books. Curriculum materials were much more likely to include notes and/or tips for facilitators within lessons or activities, activity sheets for children, and targeted support for English Language Learners. Curriculum materials were also more likely to suggest multiple ways (i.e., different modes) for children to engage in science, multiple grouping formats (e.g., pairs, whole group, individual) for children to work on tasks, and multiple ways for children to showcase their learning. The other support features were either not present in all of the materials or present in relatively similar frequencies in all of the materials.

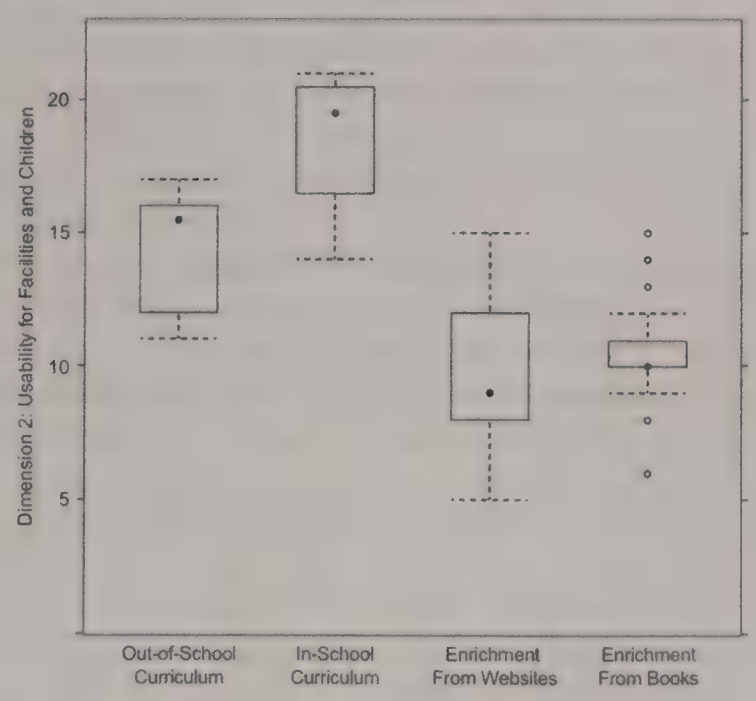

Figure 2. Box and Whisker plot for Dimension 2 (Usability for Facilitators and Children) of the materials coding scheme, grouped by category.

Engagement for children and relevance to their lives. As illustrated in Figure 3, the lessons and activities in the two curriculum categories scored higher in support features for the third dimension, engagement for children and relevance to their lives, than the lessons and activities in the enrichment categories. Both enrichment categories were very low on this dimension, highlighting the lack of support for instructional options for children, and lack of guidance for facilitators to help engage children in science. Quite differently, curriculum materials were much more likely to situate the learning in an engaging context, such as a dramatic scenario, real-world situation, or compelling problem/issue. Lessons and activities in both types of curriculum materials were more likely to provide suggestions for facilitators on how to connect science to the real world, provide opportunities and support for children to make choices that are consequential for engagement and learning, and provide guidance for facilitators to help children make choices or carry out plans. Other support features in this dimension were similarly present or absent across the two categories of materials.

Promotion of scientific thinking, reasoning, and practice. For the fourth dimension, promotion of scientific thinking, reasoning, and practice, Figure 4 shows that the lessons and activities across all the curriculum and enrichment categories scored much more similarly to each other than on the other three dimensions. Moreover, all four materials categories had high variation, especially out-of-school curriculum materials. Still, within this dimension, curriculum materials were more likely to provide guidance

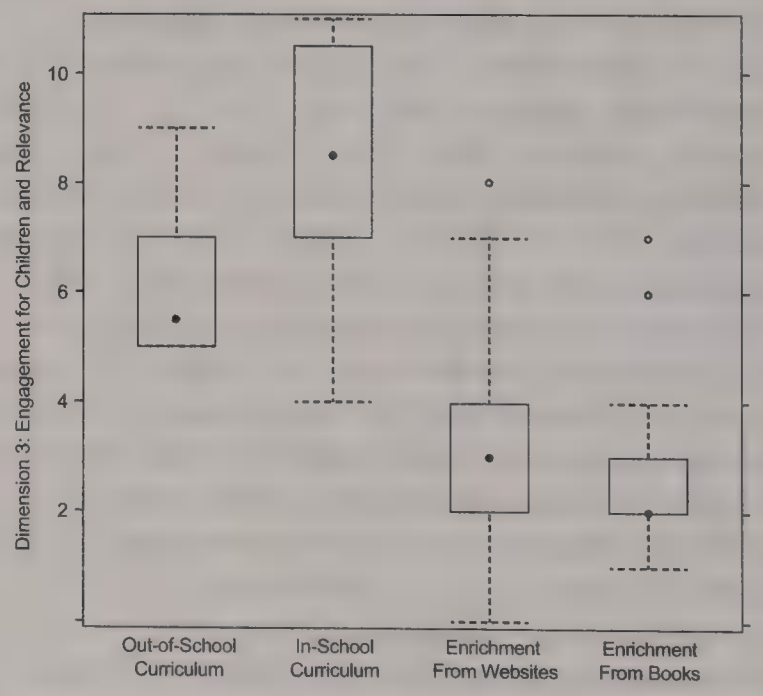

Figure 3. Box and Whisker plot for Dimension 3 (Engagement for Children and Relevance to Their Lives) of the materials coding scheme, grouped by category.

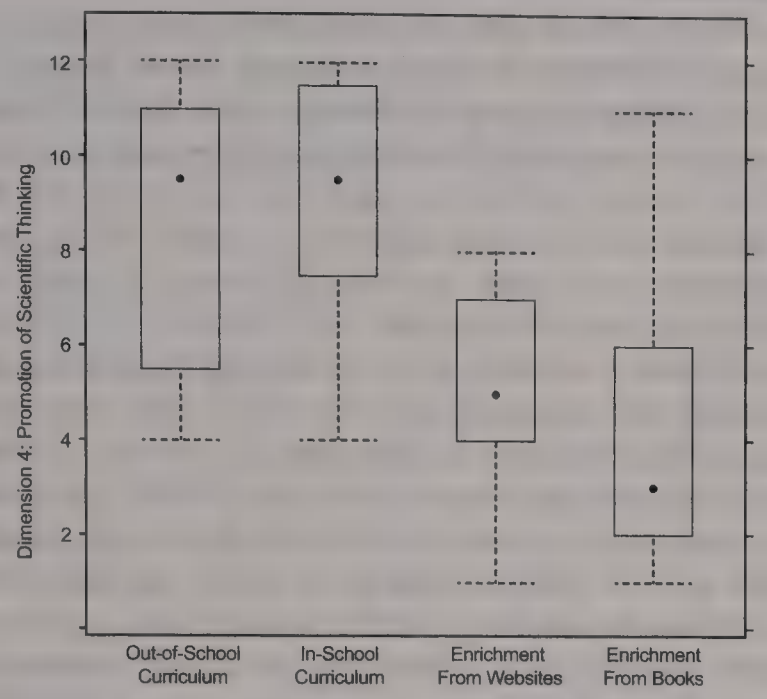

Figure 4. Box and Whisker plot for Dimension 4 (Promotion of Scientific Thinking, Reasoning and Practice) of the materials coding scheme, grouped by category.

to facilitators to help children think, reason, and reflect about science; questions for facilitators to elicit ideas, questions, and contributions during discussion; and strategies for facilitators to encourage children to make claims, weigh evidence, collect, analyze, and interpret data, make and critique scientific explanations, and communicate or present findings. Other support features in this dimension were either similarly present or absent across the two categories of materials.

Differences within categories. In our closer examination of the two types of materials from the enrichment category, several notable differences emerged. A rationale for learning goals was more likely to be included in lessons or activities from books (E2) than to be included in lessons or activities from websites (E1). However, E1 materials were more likely to situate learning within a context and to include prompts to encourage or support learner interest in science than were E2 materials.

There were also distinctions between the features likely to be included in out-of-school (C1) and school-based curricula (C2). C1 materials more often included materials for activities for the facilitators to use, materials for children to use, and prompts to encourage/support an interest in science. C2 materials more often included a rationale for learning goals, suggestions for adapting/extending activities, directions/procedures for children to follow, explanations situating learning in a context, opportunities for children to make choices consequential for learning, and guidance for facilitators to help children make choices or carry out plans.

Staff Use of Instructional Materials

Our interviews with coordinators and facilitators across sites provided insight into how instructional materials were selected and used for planning and enacting science. Site coordinators and facilitators reported that they were guided by a number of considerations when reviewing possible lessons and activities. Considerations included the cost of resources needed to implement; whether the materials included activities that children would enjoy and be capable of doing; the alignment of the lessons or activities to the skills, knowledge, and interests of staff; and the complexity of planning and implementing with the materials. Site coordinators and facilitators emphasized that they reviewed materials with an eye toward selecting those that they believed would help staff enact engaging and meaningful science experiences with children. In this endeavor, they primarily focused attention on individual lessons and activities, and made judgments about how easy or difficult a "lift" each would be for staff to use to create a science experience. Site coordinators and facilitators, while being purposeful in selecting materials that they perceived would be supportive of staff, did not report that they looked for specific support features, such as pedagogical supports, within materials. Rather, they attended to broad aspects related to the feasibility of staff implementing the materials, such as clear instructions, familiar or easy-to-grasp science content, and minimal time for preparation and cleanup.

The site coordinators and facilitators we interviewed all reported that they typically planned for short term, stand-alone science experiences. This was the case for coordinators and facilitators whose sites relied on enrichment materials as well as for those whose sites primarily used curricular materials. The general approach shared by coordinators and facilitators across sites was to identify lessons or activities within materials to support planning and implementation of one afterschool science session at a time. Some reported that they organized their selections around topics or themes, such as environmental sustainability, and sometimes chose multiple activities to match with a particular theme, but they did not select and plan activities for sequenced sessions that would explicitly link the learning experiences or build upon one another. Coordinators and facilitators who used primarily curricular materials reported that they used these materials flexibly and primarily as resources for finding stand-alone activities.

Across sites, coordinators and facilitators reported that they conducted searches on the Internet to find lessons and activities. Those who mainly used enrichment materials at their sites identified the Internet as the primary source for lessons and activities, followed by science activity books.

Coordinators and facilitators who mostly relied on curricular materials also reported that they conducted Internet searches to find supplemental lessons and activities. Similarly, they typically did not search online for sequenced science experiences and instead sought to identify promising easy-to-implement stand-alone science activities.

Discussion

Afterschool site coordinators nominated a wide range of instructional materials that fell into two large categories: curricular materials and enrichment materials. They reported using primarily enrichment materials in the form of stand-alone lessons and activities selected from books and websites. In our analysis, we found that enrichment materials had fewer support features for facilitators and children that could aide in planning and enactment. Curricular materials, both those designed for school settings and those designed for out-of-school settings, were reported to be used much less frequently, yet were found in our analysis to be much more likely to have support features aligned with current recommendations for quality afterschool science (e.g., NRC, 2009) and with learning goals reported by site coordinators and facilitators.

Of note is that not all of the enrichment materials we analyzed were lacking in support features. There were some materials that did include support features for facilitators and children. However, among those enrichment materials that did include support features we found that they varied greatly in the number and nature of the supports. By far, the predominance of enrichment materials used across afterschool sites included minimal support features.

In our analysis of materials that were expressly designed for afterschool settings, we found that they often included support features that aimed to address the constraints and needs of the typical afterschool space. For instance, these materials tend to include flexible time frames for enacting activities, guidance for organizing and interacting with groups of children, science background information described for a layperson, and easy-to-learn strategies for encouraging children to collaborate and share ideas. One set of afterschool materials we reviewed included a collection of sequenced sessions so that children could build their science understanding over time, but these same materials were also designed so that children's participation in any one session was not dependent upon completing the prior session. In this way, the materials accommodated flexible attendance—an important characteristic of the afterschool setting.

Despite having an attractive range of support features, we found that materials expressly designed for afterschool settings were not widely used across afterschool sites. From our interview data with site coordinators and our past case studies of afterschool programs (Lundh, House, Means, & Harris, 2013), we know that there are many factors that site coordinators weigh when deciding on instructional materials. These factors include cost and ease of access to the materials, perceived time and resources needed to plan and implement, alignment to the skills and interests of facilitators, and the enjoyment level for children. Many of the afterschool materials in our review were found to include features that appeared to match well with what site coordinators reported as important for the high-quality implementation of science at their sites. Yet, we also know that site coordinators and facilitators tended to plan for the short term and preferred stand-alone science activities. They conducted searches on the Internet to identify and develop or refine activity ideas rather than to identify sequenced materials or comprehensive instructional resources. Thus, the low uptake of afterschool instructional materials may be due in part to limited awareness of the value of them. Our research shows that by relying primarily on stand-alone activities from books or websites, facilitators likely miss out on support features that could help them enact meaningful science experiences with children.

It is also important to emphasize that while a particular instructional material might score high across multiple dimensions it does not necessarily follow that the material will be easily enacted by afterschool staff. The usability of instructional materials in real-world afterschool settings may depend on a range of factors, such as facilitator preparedness, time for planning and enactment, and fit with program goals and routines. For these reasons, it would not be suitable to select materials solely on the basis of dimension scores. Rather, we hold that the dimensions can provide good guidance when reviewing materials for their fit with current perspectives on how learners can best be supported in out-of-school settings, as described in the NRC's synthesis report (NRC, 2009) on informal science learning.

An important limitation of our study is that we did not examine how the materials were actually implemented at afterschool sites, nor did we examine whether or not facilitators were using the support features that were available to them and/or what features were most beneficial and in what ways. In recent years, the science education community has been building a rich knowledge base on the role of educative features in curriculum materials (e.g., Arias, Bismack, Davis, & Palincsar, 2016; Wilson, Schweingruber, & Nielsen, 2015). Much of this work has focused on school science curriculum materials. While there is much that can be learned from formal settings, there is a great need for studies on instructional materials and their effectiveness in informal

environments. Such research could help the science education community better understand the ways in which materials can be designed to effectively support science learning experiences in everyday afterschool programs.

Conclusions

There is broad agreement that afterschool has tremendous potential for offering rich science learning experiences for children. Well-designed instructional materials, with features that align with current perspectives of what makes for quality afterschool science, could help afterschool facilitators and children realize that potential. Of course, instructional materials are but one component of a larger system of resources necessary for ensuring high-quality science programming. They are, however, an essential part of that system and if designed with the unique affordances of the afterschool space in mind, they hold promise for supporting facilitators in implementing meaningful experiences that can help all children become engaged and enthusiastic learners of science.

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Keywords: afterschool science, elementary students, instructional materials

[1]We distinguish these more "typical" programs from those established solely for the purpose of implementing specialized science education programs.

Appendix: Materials Coding Scheme

Dimension 1. Content and Structure of Activities

Feature	Code	Indicator
1.1. Science learning goals: Does the material include explicit learning goals?	1.1.A1.	Identifies science content among its learning goals
	1.1.A2.	Identifies science practice among its learning goals
	1.1.A3.	Identifies engagement, motivation, attitude toward science among its learning goals
	1.1.B1.	Science content learning goals are explicitly aligned to benchmarks/standards
	1.1.B2.	Science practice learning goals are explicitly aligned to benchmarks/standards
	1.1.B3.	Engagement, motivation, attitude toward science learning goals are explicitly aligned to benchmarks/standards
	1.1.C.	Provides a rationale for the learning goal(s)
	1.1.D.	The age/grade level is specified
1.2 Activities: Does the material include one or more activities and are they sequenced to help children make progress toward achieving key science learning goals?	1.2.A.	Stand-alone activity
	1.2.B.	The activity is part of an organized group of activities (note how grouped, e.g., by topic, theme, chapter etc.)
	1.2.C.	The activity is part of a logical sequence of activities that build toward more sophisticated understanding of science content and/or scientific practices
	1.2.D.	Provides a rationale for the sequence of activities
1.3 Time for doing science: Does the material allocate time for learning science via investigations/ projects?	1.3.A.	The activity extends beyond one session or connects to a prior or next activity
	1.3.B.	Time frame is specified in the material for carrying out activities/tasks

Dimension 2. Usability for Facilitators and Children

Feature	Code	Indicator
2.1 Guidance for facilitators: Does the material include guidelines for enactment by the facilitator?	2.1.A.	Overview of the activity is included
	2.1.B.	Describes materials and necessary preparation
	2.1.C.	Provides materials for activities
	2.1.D.	Step-by-step guidance for how to enact
	2.1.E.	Safety guidelines
	2.1.F.	Prompts for discussion/reflection
	2.1.G.	Suggestions for adapting or extending activities
2.2 Educative features: Does the material include background information to support facilitator knowledge and practice?	2.2.A.	Background on content knowledge (e.g., glossary)
	2.2.B.	Background on children's likely ideas, including misconceptions
	2.2.C.	Notes/tips for facilitator (e.g., notes/tips for effective instruction, management, etc.)
2.3 Support for children: Does the material include supports for children to engage in scientific activity?	2.3.A.	Provides science materials for children to use during activities
	2.3.B1.	Activity provides firsthand experiences with phenomena
	2.3.B2.	Activity provides reading about science
	2.3.B3.	Activity provides secondhand experiences (e.g., demonstration)
	2.3.C.	Directions/Procedures for children to follow themselves
	2.3.D.	Activity sheets are included
	2.3.E.	Science notebook or journal for children to record work is included
2.4 Accessibility for diverse populations: Does the material provide multiple means for diverse populations to access the science?	2.4.A.	More than one way for children to learn (e.g., print materials, hands-on, video, etc.)
	2.4.B.	More than one way for children to work (e.g., individual/collaborative)
	2.4.C.	More than one way for children to showcase their learning
	2.4.D.	Supplements or guidance for facilitators to adapt activities for children with diverse needs
	2.4.E.	Supplements or guidance for facilitators to meet needs of English language learners (ELLs)
	2.4.F.	Support for ELL in the materials provided to children (e.g., illustrations, translations, etc.)

Dimension 3. Engagement for Children and Relevance to Their Lives

Feature	Code	Indicator
3.1 Connections to children's everyday lives: Does the material attempt to bridge science to children's everyday social and physical world?	3.1.A.	Includes science tasks or activities that relate to children's everyday lives
	3.1.B.	Situates learning in a context, such as a driving question, dramatic scenario, real-world situation, or compelling problem/issue
	3.1.C.	Provides suggestions for community involvement and/or connections to life at home
	3.1.D.	Provides suggestions for facilitators about how to connect science to the real world
3.2 Leverage children's prior knowledge and interests: Does the material provide prompts and support for facilitators to help children use their prior knowledge and interests for learning?	3.2.A.	Provides elicitation prompts for children's prior knowledge and interests
	3.2.B.	Prompts for children to relate their prior knowledge and own ideas/interests to the activities
	3.2.C.	Prompts to encourage children to coordinate their prior knowledge with new knowledge
	3.2.D.	Prompts to encourage/support children's developing interests in science
3.3 Choice for children: Does the material include opportunities and support for children (individual or group) to make choices about the direction of their learning?	3.3.A.	Includes opportunities for children to make choices that are consequential for engagement
	3.3.B.	Includes opportunities for children to make choices that are consequential for learning
	3.3.C.	Includes guidance for facilitators to help children make choices and/or carry out their decisions/plans

Dimension 4. Promotion of Scientific Thinking, Reasoning, and Practice

Feature	Code	Indicator
4.1 Thinking, reasoning, and reflection: Does the material provide supports/prompts for children to think, reason, and reflect about science experiences?	4.1.A.	Supports/prompts for children to question, predict, observe, and/or explain
	4.1.B.	Supports/prompts for children to reflect on their learning experiences
	4.1.C.	Guidance for facilitators to help children to think, reason, and reflect about science experiences
4.2 Collaborative discourse: Does the material provide questions or strategies for facilitators to encourage productive conversation?	4.2.A.	Questions for facilitators to use to elicit participant ideas, questions, and contributions during discussion
	4.2.B.	Strategies for facilitators to encourage children to listen to and build upon one another's ideas
	4.2.C.	Strategies for facilitators to encourage children to make claims and weigh evidence during discussion
4.3. Scientific inquiry practices: Does the material include activities that engage children in a range of scientific inquiry practices?	4.3.A.	Pose and/or pursue researchable or investigable questions
	4.3.B.	Design experiments and/or investigations
	4.3.C.	Conduct experiments and/or investigations
	4.3.D.	Collect, analyze, and interpret data
	4.3.E.	Build and/or use models to represent phenomena, test designs, or show ideas/understandings
	4.3.F.	Make and critique scientific explanations
	4.3.G.	Communicate/present findings

PROBLEMS section

Ted Eisenberg, *Section Editor*

This section of the Journal offers readers an opportunity to exchange interesting mathematical problems and solutions. Please send them to Ted Eisenberg, Department of Mathematics, Ben-Gurion University, Beer-Sheva, Israel or fax to: 972-86-477-648. Questions concerning proposals and/or solutions can be sent e-mail to eisenbt@013.net. Solutions to previously stated problems can be seen at http://www.ssma.org/publications.

Solutions to the problems stated in this issue should be posted before December 15, 2017

• **5457**: *Proposed by Kenneth Korbin, New York, NY*

Given angle A with $\sin A = \frac{12}{13}$. A circle with radius 1 and a circle with radius x are each tangent to both sides of the angle. The circles are also tangent to each other. Find x.

▪ **5458**: *Proposed by Michal Kremzer, Gliwice, Silesia, Poland*

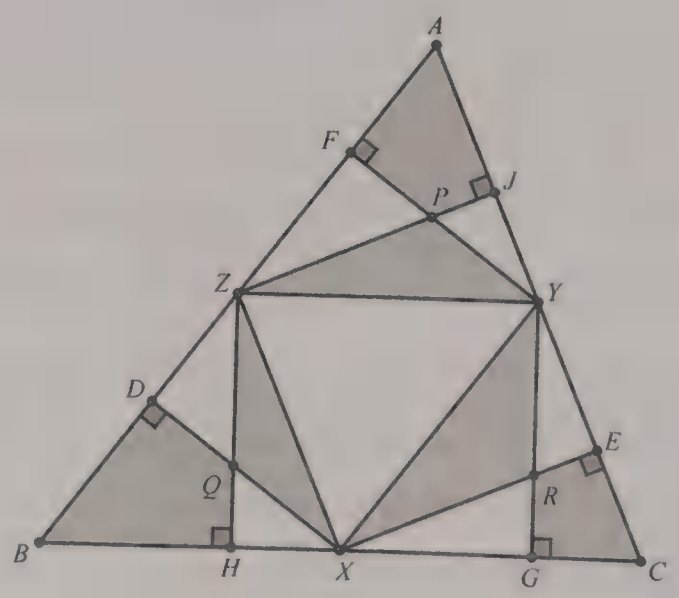
Find two pairs of integers (a, b) from the set $\{1, 2, 3, 4, 5, 6, 7, 8, 9\}$ such that for all positive integers n, the number

$$c = 537aaa\underbrace{b \ldots b}18403$$

is composite, where there are $2n$ numbers b between a and 1 in the string above.

• **5459**: *Proposed by Arsalan Wares, Valdosta State University, Valdosta, GA*

Triangle ABC is an arbitrary acute triangle. Points X, Y, and Z are midpoints of three sides of $\triangle ABC$. Line segments XD and XE are perpendiculars drawn from point X to two of the sides of $\triangle ABC$. Line segments YF and YG are perpendiculars drawn from point Y to two of the sides of $\triangle ABC$. Line segments ZJ and ZH are perpendiculars drawn from point Z to two of the sides of $\triangle ABC$. Moreover, $P = ZJ \cap FY$, $Q = ZH \cap DX$, and $R = YG \cap XE$. Three of the triangles and three of the quadrilaterals in the figure are shaded. If the sum of the areas of the three shaded triangles is 5, find the sum of the areas of the three shaded quadrilaterals.



• **5460**: *Proposed by Ángel Plaza, Universidad de Las Palmas de Gran Canaria, Spain*
If $a, b > 0$ and $x, y > 0$ then prove that

$$\frac{a^3}{ax+by} + \frac{b^3}{bx+ay} \geq \frac{a^2+b^2}{x+y}.$$

• **5461**: *Proposed by José Luis Díaz-Barrero, Barcelona Tech, Barcelona, Spain*
Compute the following sum:

$$\sum_{n=1}^{\infty} \frac{\cos(2n-1)}{(2n-1)^2}.$$

• **5462**: *Proposed by Ovidiu Furdui, Technical University of Cluj-Napoca, Cluj-Napoca, Romania*
Let $n \geq 1$ be an integer. Calculate

$$\int_0^{\frac{\pi}{2}} \frac{\cos x}{\left(1+\sqrt{\sin(2x)}\right)^n} dx.$$

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Review Information:
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- Design/Instrumentation/Procedure
- Data Analysis/Results
- Discussion/Conclusions
- Written presentation/style
- Adds new knowledge

SCHOOL SCIENCE AND MATHEMATICS

contents

Volume 117 • Number 6 • October 2017

225 **Editorial**
Integrated STEm or Integrated STEM?
William S. Walker, III

228 **Call for Proposals**

229 ***Peruvian Food Chain Jenga: Learning Ecosystems with an Interactive Model***
Beau Hartweg, Daniella Biffi, Yohanis de la Fuente, Ummuhan Malkoc, Melissa E. Patterson, Erin Pearce, Morgan A. Stewart, Molly Weinburgh

239 ***Middle School Mathematics Teachers' Perceptions of the Common Core State Standards for Mathematics and Its Impact on the Instructional Environment***
Jon D. Davis, Jeffrey Choppin, Amy Roth McDuffie, Corey Drake

250 ***How Picture Books on the National Science Teacher's Association Recommend List Portray Scientists***
Donna Farland-Smith, Kevin D. Finson, Cecile M. Arquette

259 ***A Districtwide Study of Automaticity When Included in Concept-Based Elementary School Mathematics Instruction***
Daniel McGee, Patrick Richardson, Meredith Brewer, Funda Gonulates, Theodore Hodgson, Rebecca Weinel

269 ***Examining the Types, Features, and Use of Instructional Materials in Afterschool Science***
Cynthia M. D'Angelo, Christopher J. Harris, Patrik Lundh, Ann House, Tiffany Leones, Carlin Llorente

282 **Problems Section**
Ted Eisenberg

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